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SCIENTIFIC

WRITING

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FOREWORD

The vast development of modern science has imposed heavy demands and grave responsibilities upon scientists and technologists alike. Explorations now under way in the natural, social, and applied sciences must be recorded and transmitted. But the scientist is no longer at liberty to direct his attention exclusively to his fellow-specialists; he must also reach administrators, statesmen, policy-makers, boards, and other scientists in other fields. Increasingly he must interpret for the general public the discoveries that emerge from the laboratory to transform our daily lives.

Even in practical affairs the written word grows in volume and significance. Efficient operation of commerce, agriculture, industry, and government requires skillful scientific and technical reporting. No longer can the report be taught as mere adherence to a rigidly prescribed pattern; it must be viewed as the product of profound investigation and analysis, of discernment and discrimination.

Scientific Writing is concerned with the problems faced by the scientists, technologists, and industrialists in communicating their findings. It is applicable to the general field of articles and reviews as well as the specialized area of technical reporting. The text proper divides logically into three parts.

Chapters 1 through 6 are unique in their emphasis upon the intellectual activity that must precede composition. Scientific writing being as much a way of thought as a mode of expression, the opening chapter defines and elaborates the method underlying all scientific investigations and conclusions. Chapters 2 through 6 examine elements of scientific procedure such as recognition or formulation of a problem, accurate definition, precise terminology, and the fundamentals of collecting, analyzing, evaluating, and logically interpreting data.

Chapters 7 through 9 concern the problems of communication. Writing for the expert requires care and precision, but writing for the nonspecialist presents vocabulary obstacles that can be surmounted only by considerable effort and ingenuity. Chapter 7 is devoted to this matter. It is followed by a description of scientific style as it has developed over the years, and by suggestions for departures from tradition that are permitted and sometimes required when the work is addressed to the non-

technical or semitechnical reader. Chapter 9 analyzes the fundamental techniques of exposition.

Chapters 10 through 15 treat the elements and structure of various types of papers, including the report, the review, the thesis, the research paper, the abstract, the case history, and the book review. The long-form report is dealt with at length, as well as the short report so extensively employed today in business and industry. Aware that in practice the report assumes diverse forms, the authors have wisely focused their attention upon the function of the report, and emphasized the basic elements of reporting such as the writer's alertness to the nature and needs of the reader, his understanding of the use that will be made of the report, and the means of achieving pattern, clarity, and effectiveness. Although the reader is introduced to the practices that are common in the formulation of reports, he is constantly reminded of the need to remain flexible in order to adapt his reporting to the demands of special conditions that will arise in his professional career. The validity and effectiveness of a report depend not upon a rigid form but upon the proper focusing of the problem, the sharpness of the terminology, the efficiency of the arrangement, and the soundness of the evidence and logic.

This broad and philosophical approach is supplemented by instruction including the organization, outlining, documentation, and the preparation and use of graphic and pictorial illustration in each type of paper.

Other features that contribute to the usefulness of this book are the Study Suggestions provided for each chapter, and the wealth of illustrative material throughout the text and in Appendix A. Appendix B is devoted to letters of application and to business and technical correspondence.

W. EARL BRITTON

PREFACE

Scientific Writing has been prepared for use as both a text and a reference book. The increasing significance of scientific writing in technology, science, business, and the professions has created a growing need for skilled writers. *Scientific Writing*, then, is designed to help prepare the reader for a career in industry, science, or the professions. And it is intended to serve the individuals already at work in these fields who must cope with the urgent demands of writing.

Although the term *scientific writing* is defined in the text, it is perhaps appropriate to explain briefly here the sense in which we have used it. Traditionally and historically, scientific writing is the literature of science as distinct from belles-lettres. Since the scientist frequently directs his writing to scientists outside his specialty, as well as to the general public, *scientific writing* is a broader term than *technical writing*, which includes only the writing the scientist does in addressing fellow specialists or in connection with technological applications of scientific principles. Factual writing in the areas outside the natural sciences may in a broad sense be termed scientific when it submits to the disciplines of method, objectivity, accuracy, clarity, and precision. Scientific writing in the highest sense taxes the resources of language, since, to translate freely an aphorism from the French, "Truth lies in distinguishing between the shades of gray."

In preparing this book we have given constant thought to achieving a logical, serviceable chapter sequence. The introductory chapters, 1 and 2, present concepts fundamental in scientific method and research and hence in scientific writing. The *problem concept* is discussed separately in Chapter 2 because of its importance in all kinds of investigative work.

The next four chapters—3, 4, 5, and 6—follow the sequence of an investigative project: the definition of terminology and the collection, analysis, and interpretation of data. Chapters 7, 8, and 9 deal with problems of composition. Chapters 10, 11, 12, and 13 treat various types of papers: the research paper, which is considered as an introduction to the different types of long scientific papers; short and long reports, abstracts, papers of device and process, case histories, and book reviews.

The last two chapters take up matters of format and of graphic and pictorial illustration. Thus the preparation of the long scientific paper

is carried from the inception of the problem to the completion of the manuscript for submission to the person who made the assignment or to the press.

The numerous examples in the text and in the Appendixes have been selected not only for their own merit but for the principles and practices they illustrate and for the variety of fields they represent. While they are for the most part current writing, older selections are included to show the timelessness of good scientific exposition. Study suggestions are offered to help the reader apply what he is learning to his own writing.

In concluding this project we take pleasure in expressing our appreciation to those who have assisted us with it. Professor W. Earl Britton of the University of Michigan, our General Editor, has evinced a constant sympathy with our aims and has offered numerous suggestions which we have found most helpful. Our thanks are due to Professor Ernest C. Hassold, the head of our department, for his encouragement and interest, to Warren Bezanson, formerly of the University of Maryland, and Arthur Thompson of the Bell Telephone Laboratories for their sound editorial advice.

We should like also to thank the staff members of the University of Louisville Library, including the Natural Science Library, and of the libraries of the University of Louisville School of Medicine, School of Law, School of Dentistry, and Speed Scientific School for their help in locating and verifying references. Miss Katharine Lewis, reference librarian, Miss Virginia Winstandley, assistant librarian, and Miss Laura Kersey, librarian of the Speed Scientific School, have in addition given generously of their personal assistance with special problems.

We are indeed grateful to the individuals and organizations who have permitted us to quote from their writings, correspondence, or publications. Most of these sources are acknowledged in the text and in the Appendixes. We are also indebted to Professor Frank E. Ryerson of the Department of English of the Speed Scientific School for permission to include in Appendix B three letters from his files. Finally we wish to acknowledge the kind and always efficient help of Mr. Ralph C. Wooton in the tasks incident to the preparation of the manuscript.

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University of Louisville, 1955

CHAPTER 1 SCIENTIFIC METHOD

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> *The unity of all science consists alone in its method, not in its material.* KARL PEARSON, The Grammar of Science.

I. MEANING OF SCIENTIFIC METHOD

It has been said that there is no science, only sciences. The word *science* is, however, used and understood by both scientists and the public to denote more than the sum total of the sciences. Science may be defined as the inquiry into the nature of the material universe through observation and experiment, an inquiry which has resulted in a systematized and continually growing body of knowledge. In any consideration of *scientific method* the four elements of this definition of science are significant: 1 the spirit of free inquiry, 2 the reliance on observation and experiment, 3 the systematization of knowledge through generalization or laws, and 4 the continuity of inquiry.

Many writers have sought to describe and define *scientific method*, and ideas concerning its meaning are still undergoing modification.

In the 1890's Karl Pearson could write, "The scientific method is one and the same in all branches, and that method is the method of all logically trained minds." [1] Some sixty years later a present-day writer in discussing changing ideas of scientific method could observe, "The statement that there is no single scientific method has become a truism only rather recently." [2] These contrasting statements emphasize the fact that in our time the methods of scientific investigation have themselves become the object of active inquiry, and that relatively simple concepts have given way to more complex ones. Scientific method is not now to be regarded as a formula or infallible rule of procedure but rather as an approach, an attitude, a combination of procedures, a set of values, which have in the past proved favorable to scientific investigation and are recognized as characteristic of it.

Implicit in the definition of science is the need for reports of inquiry. Indeed, "Reporting is an integral and inescapable factor in any research, and no research is complete without the record." [3] Scientific writing, then, is what the scientist writes in his capacity as scientist, the necessary minimum of which consumes a considerable amount of his time and effort. Such writing, then, is most successful when the writer is conscious of the functional harmony between scientific method and the form of scientific papers.

A. The Cumulative Nature of Scientific Method

Many analogies have been used to express the cumulative nature of science. One such analogy, which though often ascribed to Sir Isaac Newton dates from medieval times, compares the individual to a dwarf standing on the shoulders of a giant representing the knowledge of the past. Another analogy, suggested by the historian of science, George Sarton, compares its progress to a long climb up a lofty mountain with each worker taking up the trail where the one before him left it.

It has often been noted that the desire to know is as much a part

[1] Karl Pearson, *The Grammar of Science*, London, J. M. Dent & Sons, Ltd., 1937, p. 15.

[2] Gerald Holton, "On the Duality and Growth of Physical Science," *American Scientist*, 41:89, January 1953.

[3] Robert S. Gill, "The Scientific Author as I Have Known Him," *Science*, 119:3A, April 23, 1954.

of man as the desire to create. Thomas Henry Huxley has dramatized the beginnings of man's search for knowledge by describing a savage in prehistoric times already applying the principles of observation and inference.

> I cannot but think that the foundations of all natural knowledge were laid when the reason of man first came face to face with the facts of Nature; when the savage first learned that the fingers of one hand are fewer than those of both; that it is shorter to cross a stream than to head it; that a stone stops where it is unless it be moved, and that it drops from the hand which lets it go; that light and heat come and go with the sun; that sticks burn away in a fire; that plants and animals grow and die; that if he struck his fellow savage a blow he would make him angry, and perhaps get a blow in return, while if he offered him a fruit he would please him, and perhaps receive a fish in exchange. When men had acquired this much knowledge, the outlines, rude though they were, of mathematics, of physics, of chemistry, of biology, of moral, economical, and political science, were sketched.[4]

Yet admiration for the achievements of Huxley's savage cannot obscure the fact that his conclusions are far removed from the rigidly controlled observations of the modern laboratory. This change represents not only the acquisition of knowledge but improvement in the methods of investigation through which knowledge is acquired. In part these methods are technical and mechanical: every branch of science has its tables and reagents, its petri dishes and cultures, its stethoscopes and cardiographs, its microscopes and slides, or its cyclotrons, betatrons, and synchrotrons.

When we speak of scientific method, however, we do not refer primarily to this accumulation of technique, important as it is, but to the attitudes and procedures which further scientific inquiry. This concept of scientific method is consonant with Paul Valéry's characterization of method as able "better than the mind left to its own devices" to "do the work of the mind." [5]

[4] Thomas H. Huxley, "On Improving Natural Knowledge," *Method and Results*, New York, D. Appleton and Company, 1893, p. 32.

[5] Paul Valéry, Introduction to *The Living Thoughts of Descartes*, Philadelphia, David McKay Company, 1947, p. 14.

B. The Complexity of Scientific Investigation

Some devotees of science have done scientific method a disservice by claiming too much for it. Aldous Huxley has satirized this undue reliance on the methodology of research in the character of the elder Quarles of *Point Counter Point.* Mr. Quarles had collected files, card indexes, a calculating machine, and a typewriter which would write in Greek, Arabic, or Russian. He also had an elaborately conceived plan for a learned book which he never quite got around to writing. This pseudo scientist's inability to distinguish between the mechanics and the spirit of research reminds us that scientific method is a means, not an end. It is not a routine procedure but one which must be guided by human intelligence and even by what some scientists have not hesitated to call human intuition.

The part chance plays in scientific discovery has been recognized by many commentators on the history of science. W. I. B. Beveridge [6] mentions, among other examples, accidental occurrences which led to the discovery of the Gram stain for distinguishing different bacteria, to Richet's discovery of anaphylaxis, and to the development of the Ringer solution. Here, chance is not to be confused with luck, for only the trained and perceptive person is in a position to see the possible significances of the singular occurrences and to launch an inquiry into their meaning. A biographer of Pasteur has pointed out that what often seemed to be luck in the career of Pasteur was actually the ability to select promising lines of research.

> . . . so often was Pasteur helped by apparent "luck" in the subsequent course of his scientific career that the reason for his success must be found elsewhere. Throughout his life, he displayed an uncanny gift in selecting the type of experimental material best adapted to the solution of the problem under investigation. This gift, which is common to all great experimenters, certainly consists in part of an intuitive wisdom based upon a large background of knowledge. Good fortune is offered to many, but few are they who can recognize it when it is offered in a not too obvious manner.
>
> Pasteur could have been thinking of many vital experiences of his own when he reiterated, time and time again, "In the field of experimentation, chance favors only the prepared mind." [7]

[6] W. I. B. Beveridge, *The Art of Scientific Investigation,* London, William Heinemann, Ltd., 1951, pp. 27-29.

[7] René J. Dubos, *Louis Pasteur,* Boston, Little, Brown and Company, 1950, pp. 100-01.

Research into the history of science has shown further that procedures vary with the temperament of the individual scientist and that imagination may figure more prominently than logic in the formulation of new scientific theories. Such contradictions to the popular conception of the cold logic of science have been summed up by Holton.

> . . . the essential incongruities in science, which include the element of irrationality and contradiction in scientific discovery, the discrepancy between the precision of physical concepts and the flexibility of language, the conflict between the motivating drive and the rules of objectivity—in short, the whole complexity in the relations between the individual creative scientist on one hand and science as an institution on the other.[8]

Having elaborated this paradox, Holton offers a resolution of it.

> This dilemma is resolved—and here is the second central point—*by distinguishing two very different activities, both denoted by the same word, "science":* the first level of meaning refers to *private science* (let us term it S_1), the science-in-the-making, with its own vocabulary and modes of progress as suggested by the conditions of discovery. And the second level of meaning refers to *public science* (S_2), science-as-an-institution, textbook science, our inherited world of clear concepts and disciplined formulations. S_1 refers to the speculative, creative element, the continual flow of contributions by separate individuals, each working on his own task by his own, usually unexamined methods, motivated in his own way, and uninterested in attending to the long-range philosophical problems of science. S_2, in contrast, is science as the evolving compromise, as the growing network synthesized from these individual contributions by the general acceptance of those ideas which do indeed prove meaningful and useful to generations of scientists. The cold tables of physical and chemical constants, the bare equations in textbooks, form the hard core, the residue distilled from individual triumphs of insight, checked and cross-checked by the multiple testimony of general experience.[9]

Science as an institution, it would seem, through the discipline of scientific method, has provided an environment in which the individually gifted scientist can effectively apply his creative imagination to scientific problems. Such a situation is perhaps not as paradoxical as it would appear since it has an analogue in the literary artist who

[8] Holton, *loc. cit.*
[9] *Ibid.*, p. 93.

achieves his finest expression through such a severely disciplined form as the sonnet.

II. THE CHARACTERISTIC FEATURES OF SCIENTIFIC METHOD

The historical development of scientific method has taken place in three interrelated stages: (1) observation, more or less systematic, under the guidance of theory and authority, a process practiced and sanctioned by Aristotle; (2) the rejection of authority and the turning toward inductive reasoning which marked the beginning of the modern era; (3) the development of the experimental process. The experimental process which dominates present-day science has in turn three parts: the problem, which focuses observation on a specific question or difficulty, the projection of a hypothetical solution, and the testing of the solution by experiment.

Although in general the rejection of authority and the rise of inductive reasoning became articulate with the Renaissance, and experimental method has come to be the focal point of scientific thinking only during the past three hundred years, the various branches of knowledge have arrived at different times at the successive plateaus of method. Copernicus, for example, in the sixteenth century rejected authority and maintained that the earth revolves around the sun. Vesalius and other pioneer anatomists turned at about the same time from the authority of Galen and rejected anatomical doctrine which was not verifiable from the dissection of the human body. Yet it was not until the nineteenth century that Grimm and other early philologists began a systematic and objective study of the phenomena of language and undertook a formulation of the laws that describe its changes.

William M. Smallwood [10] has shown how slowly scientific attitudes were adopted in this country. The natural historian as Smallwood has described him frequented rural areas and the unpretentious halls of our early colleges. He collected and classified, not too particular whether it was rocks, flowers, or shellfish. And always his philosophy was governed by the belief that everything in nature had its preordained purpose. These students of natural history, unmindful of controlled observation or experimental method, were nevertheless the

[10] William Martin Smallwood, *Natural History and the American Mind*, New York, Columbia University Press, 1941, p. 239 ff.

forerunners of the American geologists, botanists, and zoologists of today.

A. Reliance on Observation

What then are the principal characteristics of the scientific method as we know it today? Although authorities differ in their emphasis, they are in substantial agreement on the essential features. A common characteristic of all sciences is that they draw their basic principles from man's observations of himself and his environment. The modern era in science began when the medieval practice of referring questions to authority and speculation gave way to the modern practice of referring them to investigation and observation. The story of Galileo's famous experiment, the time and place of which have been questioned by modern scholars,[11] is a classic instance of this distinction. While the scholastic philosophers showed by theory that a heavy body must fall proportionately more rapidly than a lighter body, Galileo is reported to have dropped simultaneously two unequal weights from the tower of Pisa, thus demonstrating the contrary.

To leave the question of authority at this point, however, would be to ignore recent revolutions of thought which have obliged scientists to alter their ideas of proof and even of truth. The physics of Newton is true within the limits it covers; it does not hold true within the larger limits of Einstein's theory of relativity. Hence the word *proof* is used today with greater caution than ever before. Perhaps an acceptable statement of the matter is to say that the scientist is always prepared to revise his beliefs in the light of new evidence. "The oldest of the great scientific societies, the Royal Society of London," as C. Leonard Huskins reminds us, "placed rejection of authority at the masthead with its motto *Nullius in verba*, usually translated freely as 'not bound by the words of any man.' "[12]

B. The Inductive Approach

An understanding of the relationship between inductive and deductive reasoning is essential to an understanding of scientific method. By definition, inductive reasoning proceeds from the particular to

[11] I. Bernard Cohen, "Galileo," *Scientific American*, 181(2):40-47, August 1949.

[12] C. Leonard Huskins, "Science, Cytology, and Society," *American Scientist*, 39:691, October 1951.

the general, deductive reasoning from the general to the particular. The point at issue is not, as it is sometimes stated, which of the two is used in science. Both are essential in science, but for different purposes. If the general laws and concepts of science are not accepted *a priori* from authority, they must be established inductively from a large number of specific examples. Once a general principle has been established it may be used as a major premise from which lesser principles and applications may be deduced.

One of the best-known statements of the inductive approach occurs in Francis Bacon's *Novum Organum,* first published in 1620.

> There are and can exist but two ways of investigating and discovering truth. The one hurries on rapidly from the senses and particulars to the most general axioms, and from them, as principles and their supposed indisputable truth, derives and discovers the intermediate axioms. This is the way now in use. The other constructs its axioms from the senses and particulars, by ascending continually and gradually, till it finally arrives at the most general axioms, which is the true but unattempted way.[13]

How far Bacon can be credited with furthering the inductive approach has been questioned. Certainly he did not originate it, and the picture his work suggests of the scientist accumulating great masses of fact in broad, general groups is hardly a realistic one. However, the current emphasis on experiment has probably led to some underestimation of the importance of induction itself. Even during the past century two revolutions in thought have grown out of conclusions inductively arrived at. Darwin based his theories of evolution on the masses of biological materials he had accumulated, and Freud's theories of psychoanalysis grew out of the study of numerous case histories.

The basic weakness of Bacon's view was that he did not perceive the necessity for a guiding problem. "To follow Bacon's prescription," notes F. S. C. Northrop, "is to gather facts before one knows what facts, among the infinite number in the universe, to gather." [14] Pursuing a similar line of reasoning, Morris R. Cohen and Ernest Nagel have observed:

[13] Francis Bacon, *Advancement of Learning* and *Novum Organum,* New York, P. F. Collier & Son, 1900, pp. 316-17.

[14] F. S. C. Northrop, *The Logic of the Sciences and the Humanities,* New York, The Macmillan Company, 1947, p. 17.

> It is an utterly superficial view, therefore, that the truth is to be found by "studying the facts." It is superficial because no inquiry can even get under way until and unless *some difficulty is felt* in a practical or theoretical situation. It is the difficulty, or problem, which guides our search for some *order among the facts,* in terms of which the difficulty is to be removed.[15]

Finally, induction is incomplete until the accumulated data have been analyzed and classified. The spectacle of a research worker who has accumulated a mass of data and then has little idea what to do with it is not unfamiliar.

C. The Experimental Process

Experiment, which has been defined as observation under controlled conditions, is in modern practice likewise channeled by the problem under investigation. The sequence of operations which constitutes ideally the experimental process begins with an observation which reveals a difficulty or problem. The experimenter formulates a hypothesis to explain the difficulty; then he tests the hypothesis by experiment and draws his conclusions as to its validity.

An example of the experimental process which will repay careful study by anyone interested in scientific writing is William Harvey's renowned work on the heart and the circulation of the blood, *De Motu Cordis.* This work, first published in 1628, has so kindled the admiration of successive generations of physicians that it has been translated from the original Latin into the English idiom of three different centuries—once in Harvey's own time, twice in the nineteenth century, and in the twentieth by Chauncey D. Leake.[16]

One of the observations which led to Harvey's great discovery concerned the amount of blood pumped by the heart and the frequency of the pulse. Harvey observed that the blood in the arteries flowed away from the heart only, and at a rapid rate. This observation was incompatible with the traditional anatomy of the time, according to which the blood passed outward from the heart in both the arteries and veins with a flowing and ebbing motion. If the blood flowed rapidly outward through the arteries, as he had observed

[15] Morris R. Cohen and Ernest Nagel, *An Introduction to Logic and Scientific Method,* New York, Harcourt, Brace and Company, 1934, p. 199.

[16] William Harvey, *De Motu Cordis,* translated by Chauncey D. Leake, 3rd ed., Springfield, Ill., and Baltimore, Md., Charles C. Thomas, 1941, p. *xii.*

it to, Harvey reasoned, far more blood would be required than could possibly be formed from all the nourishment the body received unless the blood returned through another channel to the heart. Thus Harvey's observations raised a problem or theoretical difficulty. To obviate the difficulty he formulated the hypothesis that the blood did not flow in one direction only but "in a circle." Further experiment convinced him of the truth of this hypothesis, which was fully demonstrated about thirty years later when Malpighi discovered the capillaries through which the blood passes from the arteries to the veins and so back to the heart.

Harvey himself, although he appreciated the importance of his results, did not comprehend fully the significance of his method. Philosophically, like earlier followers of Aristotle, Harvey accepted Aristotle's emphasis on nature and design, and throughout his work Harvey quoted deferentially the very medical authorities his discovery was confuting.

The process of formulating principles which describe such phenomena of the universe as can be reduced to order advances through successive stages of acceptance from speculation through hypothesis and theory to law. A hypothesis must be extensively tested and much evidence for it adduced before it becomes a law. One of the conspicuous differences between the scientifically trained and the untrained is the readiness of the untrained person to accept a plausible speculation as an established principle.

D. The Principle of the Control

If observations are to be instructive, the factor immediately under consideration must be separated from others which may confuse the issue. In the word *malaria,* which means literally "bad air," our language has recorded an error which arose from uncontrolled observation. Those who first observed that malaria was associated with unwholesome air failed to distinguish between the air and the mosquitoes which infested it and consequently did not recognize the true cause of the disease. The modern practice is to avoid such errors by setting up wherever possible control groups which correspond to the experimental groups at every point except the point at issue. The procedure is familiar in experiments with nutritional values in which two like groups are fed the same diets except that the item

whose effect is to be tested (ascorbic acid, for example) is added to the diet of the experimental group but not to the diet of the control group.

Successful use of the control principle depends on a complete analysis of the factors concerned in a problem and the devising of experiments which will test only one factor at a time. The difficulties of achieving this result may be illustrated by an experiment of W. C. Allee and his co-workers,[17] who have done so much to extend our knowledge of social relations among animals. The purpose of the investigation was to test the comparative development of sunfish isolated and in groups. In one experiment two groups of sunfish were placed in aquaria. Both groups had the same total amount of water, but the individual fish of one group were separated from one another by partitions while those of the other group were not. The fish which remained together developed more rapidly than the others, but it was not possible to say that this result was due entirely to their group association because, although the volume of water for each fish was the same for both groups, the isolated fish were not able to swim as far in one direction. Thus the results might have been due either to association with the group or to what the investigators called "*Raumfaktor*."

Claude Bernard expressed the view that the principle of control or exact comparison is fundamental in the experimental approach.

> In all experimental knowledge, indeed, there are three phases: an observation made, a comparison established and a judgment rendered. . . .
>
> Now experimental reasoning is absolutely the same, whether in sciences of observation or in experimental sciences. We find the same judgment by comparison based on two facts, one used as starting point, the other as conclusion, of our reasoning. Only in the sciences of observation, the two facts are always observations; while in the experimental sciences, the two facts may be taken exclusively from experimentation, or at the same time from experimentation and from observation, according to the special case and according to how deeply we go into experimental analysis.[18]

[17] W. C. Allee, Bernard Greenberg, G. M. Rosenthal, and Peter Frank, "Some Effects of Social Organization on Growth in the Green Sunfish, Lepomis cyanellus," *Journal of Experimental Zoology*, 108:1-19, June 1948.

[18] Claude Bernard, *An Introduction to the Study of Experimental Medicine*, translated by Henry Copley Greene, New York, Henry Schuman, Inc., 1949, pp. 12, 16.

E. Objectivity

The distinction between the objective and the subjective is expressed in the basic words "object" and "subject." The *objective* has its source in phenomena external to the individual; the *subjective* lies within the mind of the individual and is colored by his temperament. Such a distinction is relative rather than absolute, for we can know the external world only as the senses perceive it and the mind interprets it. However, though relative, the distinction is fundamental to the distinction between art and science. In art the individual is the supreme authority. In science the individual bases his conclusions on observations of natural phenomena and must be prepared to submit them to others for corroboration.

This obligation of the scientist to submit his results to the critical examination of others lays upon him two corollary obligations: first, he must observe accurately and measure exactly; second, he must record his results in language so precise that any qualified person can follow his reasoning and if necessary repeat his experiments. Contrasting objective and subjective statements, Cleanth Brooks and Robert Penn Warren observe:

> We may write, "The water was 31 per cent saturated with filterable solids," or we may write, "The water was stained a muddy brown." We may write, "The man was 5 ft. 3½ in. tall," or we may write, "He was a runty little fellow." We may write, "The animal caught was a mature male of the species *Rattus norvegicus* weighing 1 lb. 3½ oz.," or we may write, "We caught a fat brown rat." [19]

To this description of the characteristic features of scientific method two cautionary observations must be added. All the features of scientific method, though they may be considered separately, are closely interrelated. Moreover, the history of scientific method has been one of organic development which is presumably still continuing. Consequently, any statement of it can be only as of now.

III. PROBLEMS OF METHOD IN THE SOCIAL SCIENCES

Social scientists disagree both as to the propriety of considering the social sciences true sciences and as to the usefulness of scientific

[19] Cleanth Brooks and Robert Penn Warren, *Modern Rhetoric*, New York, Harcourt, Brace and Company, 1949, p. 34.

method in their pursuit. A view which has long been influential derives largely from the position of the nineteenth century philosopher Auguste Comte, who held that the sciences have become *positive* according to the degree of their remoteness from man. The social sciences would thus be considered comparable to the natural sciences but in an earlier stage of development. Social scientists have, however, pointed out numerous differences between natural science and social science: that a systematic science deals chiefly with universals, human history with particulars; that prediction on the basis of the past is far more hazardous when concerned with human than with natural phenomena; that where man himself is involved as a social being he can hardly avoid concerning himself with "ends" as well as with the truth. The question, as Carl L. Becker has pointed out, is essentially one of definition.

> The one thing that all scientists have in common is not a special technique, but a special attitude of mind towards their several enterprises. This attitude is simply the desire to know, in respect to the particular matter in hand, what is true about it, irrespective of any practical or esthetic or moral implications that may be involved in the truth that turns up. This does not mean that the scientist in any branch of learning is indifferent to these implications, but only that for the purpose of his inquiry he must disregard them. If one asks how he can afford to disregard them, the answer is that his enterprise proceeds upon the fundamental assumption that knowing what is true is itself a primary value upon which all other values must in the long run depend. In this sense history and the social studies are branches of science—that is to say, the pursuit of knowledge for its own sake.[20]

Yet, as Becker further notes:

> This is the fundamental difference between the natural sciences and the social studies; whereas the behavior of material things remains the same whatever men learn about it, the behavior of men is always conditioned by what they know about themselves and the world in which they live.[21]

A. The Social Scientist and His Material

From the quoted material above one point emerges clearly: however much social science may be influenced by the methods of the

[20] Carl L. Becker, "The Function of the Social Sciences," *Science and Man*, New York, Harcourt, Brace and Company, 1942, p. 243.
[21] *Ibid.*, p. 244.

natural sciences, the worker in the social sciences has a special relationship—intellectual and emotional—to his own studies. As the embryologist George W. Corner once facetiously put it, if man "is an ape he is the only ape that is debating what kind of ape he is." [22] This special relationship of the social scientist to his material operates in two ways. One effect brings the observer closer to his material.

> In human behavior we have a kind of direct knowledge of motives, whereas we only infer the existence of physical forces from observation of the changes specific to each. Hence, the irresistible urge to treat motives as real.[23]

The other effect is that the objective and impersonal attitude of the scientist is more difficult to maintain where human factors are directly involved.

Since controls in human relations are difficult to set up, it is more difficult to test hypotheses in the social than in the natural sciences. Consequently a tendency may develop to evolve theory without subjecting it to rigorous testing. Notwithstanding the difficulties encountered, however, present-day social science is characterized by the strength of the movement toward setting up more effective controls and devising more accurate means of measurement. In the opinion of one social scientist, "the movement to make the social studies scientific began to take form in the middle of the eighteenth century, gained decided vigor with Comte, and continues as the most significant influence in social science today." [24]

B. Scientific Method and Social Science

The difficulties of formulating method in social sciences are admirably summarized by Stuart A. Rice in his introduction to *Methods in Social Science*, a collection of case studies in method compiled under the direction of the Committee on Scientific Method in the Social Sciences of the Social Science Research Council. After consid-

[22] George W. Corner, *Ourselves Unborn*, New Haven, Yale University Press, 1944, p. 131.

[23] Frank Knight in *Methods in Social Science*, edited by Stuart A. Rice, Chicago, The University of Chicago Press, 1931, p. 67.

[24] Wilson Gee, *Social Science Research Methods*, New York, Appleton-Century-Crofts, Inc., 1950, p. 162.

ering various interpretations of method, Rice arrives at a working definition.

> . . . method must be regarded as a term of variable meanings. In the present work it seemed desirable to employ whatever versions of the term would have utility for the interpretation and the further development of social science.
>
> One version which will be stressed from this point onward has not been scrutinized in the foregoing discussion: namely, that view of method which identifies it with the concepts and assumptions underlying scientific inquiry, and in terms of which the major aspects of a problem are formulated. Method in this sense precedes, either explicitly or implicitly, the employment of methods in any more limited sense. The concepts and assumptions underlying scientific investigation are frequently undiscerned, in spite of their all-pervading and far-reaching consequences upon it. Differences in the formulations of investigators are more likely to proceed from differences in their ways of conceiving problems and data than from any other methodological cause. Hence it would seem that what may be called the "conceptual" version of method refers precisely to those aspects of social inquiry whose clarification would be most beneficial. Moreover, since this interpretation of the term can be made to include the more limited interpretations, it seems to be the most general and the most fundamental that can be employed.
>
> The hard-headed, factual-minded type of investigator, most akin among his fellows to the "practical man" among laymen, will remain skeptical of the value of this interpretation. He will ask his science for "facts," and be willing to "let the concepts go." He would like to build a social science out of such tangible units as bushels of wheat, votes of electors, birth-rates, and reaction times. By binding such units together in mathematical formulas, he thinks, social science may approach the solidity of the so-called "natural" sciences. But before quantitative methods can be employed it is necessary to identify and define the objects to be counted. Even prior to this it is necessary to formulate the problem with respect to which—and delimit the field within which—enumeration is to occur. In social science these steps offer peculiar difficulties. They are inseparable from the investigator's concepts and assumptions.[25]

The studies in *Methods in Social Science* are grouped in relation to "three broad objectives in social science": definition, ascertainment of sequence and change, and discovery of relations. The last

[25] Stuart A. Rice, *Methods in Social Science*, Chicago, The University of Chicago Press, 1931, pp. 7-8.

is subdivided into interpretations of relationship among unmeasured factors, attempts to determine relations among measured but experimentally uncontrolled factors, and attempts to determine quantitative relations among measured and experimentally controlled factors. In a more recent study of methodology in social science the author [26] offers the following analysis: the case method, the statistical method, the historical method, the survey method, and the experimental method.

It is evident that many of the concepts with which the social scientist deals must be expressed in verbal terms. Qualitative differences, unlike quantitative differences, must be expressed in words. The inference is justified that the exactness of the social sciences will be closely limited by the degree to which language can be made exact and precise.

IV. THE *PROBLEM* IN MODERN SCIENTIFIC INVESTIGATION

The function of the *problem* in scientific research is perhaps less well understood than are some of the concepts of scientific method which received emphasis at an earlier time. Nevertheless, an understanding of the problem concept is essential to an understanding of modern scientific research. This concept has two elements. One, concentrating on a small division of the subject, was postulated by Descartes in one of the famous rules in his *Discourse on Method:* "to divide each of the difficulties under examination into as many parts as possible, and as might be necessary for its adequate solution." [27] The other element of the problem concept is the formulation of the problem as a question. The popularity of "fact-finding" agencies attests to the wide use of the question-asking approach as a means of focusing the problem. The problem concept has had such a wide influence that it would be scarcely possible to find a field of research which has not been affected by it. For this reason an understanding and application of the concept are frequently of the highest usefulness in clarifying the ideas of the scientific writer, and this aspect of the subject is further developed in Chapter 2.

Many philosophers and scientists have described various features

[26] Gee, *op. cit.*

[27] *The Living Thoughts of Descartes,* presented by Paul Valéry, Philadelphia, David McKay Company, 1947, p. 57.

of scientific method. Naturally the points of emphasis in these accounts have differed. To some the dominant feature of scientific method is accurate quantitative measurement; to others, hypothesis and experiment form the crucial point. Within recent years many observers of our social order have contended that our whole society would gain if the use of scientific method, particularly the application of the problem concept, were extended. In these broader relationships, scientific method is not so much a method as a way of thought or, as John Dewey termed it, "the scientific habit of mind."

STUDY SUGGESTIONS

1. Compare the definitions or descriptions of science which follow. What does each contribute? To what do you attribute the differences among them?
   a. "Almost by definition, I would say, science moves ahead." James B. Conant, *On Understanding Science.*
   b. "The educated layman of the eighteenth century . . . knew that the pursuit of science would yield many useful or practical innovations. But he also knew—and perhaps even better than we do—that primarily science is a way of looking at the external world and uncovering its fundamental truths." I. Bernard Cohen, *Science, Servant of Man.*
   c. " 'Science' is a label for our attempts to find out how the universe works by means of careful observation rather than armchair speculation." Stuart Chase, *Power of Words.*
   d. "Science is not the mere collection of facts, which are infinitely numerous and mostly uninteresting, but the attempt by the human mind to order these facts into satisfying patterns." C. N. Hinshelwood, *The Structure of Physical Chemistry.*
   e. "True science is distinctively the study of useless things. For the useful things will get studied without the aid of scientific men. To employ these rare minds on such work is like running a steam engine by burning diamonds." Charles S. Peirce, "The Scientific Attitude."
2. In his Preface to the first number of *The American Journal of Human Genetics*, September 1949, H. J. Muller urges scientists engaged in the study of genetics to dissociate themselves from passion and prejudice and "to hold fast to the hard-won results of painstaking experiments, observations and calculations, to maintain objectivity of method, independence of thought, searchingness of analysis and freedom of criticism, no matter what 'authority' may thereby be challenged." Com-

pare the points mentioned by Muller with those discussed in the foregoing chapter.

3. What aspect of scientific method is stressed by Bernard in the following sentence from *An Introduction to the Study of Experimental Medicine?* "One must be brought up in laboratories and live in them, to appreciate the full importance of all the details of procedure in investigation, which are so often neglected or despised by the false men of science calling themselves generalizers."
4. Discuss the implications in the change in attitude toward scientific method which has become evident since the beginning of the present century.
5. Find out all that you can about the methods of work of one of the following scientists: Sir Isaac Newton, F. A. Kekule, Robert Boyle, W. Beaumont, Ramón y Cajal. Comment on your findings in connection with the discussion in the foregoing chapter.
6. With what hypotheses are the following individuals identified? Copernicus, Priestley, Lamarck, Pavlov. Which of these hypotheses have been substantiated by later investigations?
7. Draw up a list of subordinate topics which would be involved in this question: How far will it be possible for man to go in developing a science of human behavior? Would this, with provision for library reading, be a suitable subject for a panel discussion?
8. In what ways are scientific method and scientific writing related?

CHAPTER 2 THE PROBLEM CONCEPT

> *A problem is really a springboard for a leap into the unknown.* R. E. GIBSON, The Arts and the Sciences, American Scientist, July 1953.

I. SIGNIFICANCE OF THE PROBLEM

Modern inquiry into scientific method has revealed increasingly that the ability to perceive a problem in what others would accept as commonplace or trivial is a distinguishing mark of the true scientist. History tells of Galileo watching the lamps of the cathedral of Pisa as they swayed back and forth on their long chains. Lamps had swayed back and forth before the eyes of countless watchers, but of them all, Galileo is remembered because only he observed that the long and the short strokes occupied the same time; and his observation led to the discovery of the principle of the isochronism of the pendulum. In recent times Sir Alexander Fleming has been acclaimed

for his discovery of penicillin. Actually the mold which led to the discovery of penicillin had been known to other scientists before Fleming. Fleming alone saw a problem: might not this mold capable of destroying bacteria be useful to man?

Henri Becquerel likewise had a gift for seeing the significance in chance observations. The work of his father had led Becquerel to experiment with the salts of uranium. One day while Becquerel was exposing to sunlight a photographic plate covered by a black paper on which he placed a salt of uranium, the sunlight disappeared just after the exposure had been started. When the plate was developed, the impression was as strong as if the plate had had a full exposure to sunlight. This led Becquerel to repeat the experiment without sunlight; the results were the same. Thus a chance shadow was one of the circumstances which led to the discovery of radioactivity.

However, such selections from the headlines of history present to a degree a false, or at least a partial, picture. Science advances not only through chance observations but through the painstaking work of countless investigators, each working on his own problem, and all pooling their knowledge. Such, for example, is the current attack on the problem of cancer. Cancer is a complex of many problems—some chemical, some morphological, some pathological, some clinical, and some physiological. The individual investigators, each taking his own small part of the problem, are co-operating in the attack on the greater problem, confident that in the end it will be solved.

The problem concept is of major importance to the scientific writer since a clear perception of the problem is a first step toward a lucid and effective paper. For the student it is the presence of a problem which distinguishes a research paper from mere reference work. This distinction applies even in fields outside science. The student who goes to the library to "look up" William Dean Howells is merely doing reference work. The student who analyzes the American business man of different eras as portrayed in Howells' *The Rise of Silas Lapham*, Theodore Dreiser's *The Titan*, and Sinclair Lewis' *Babbitt* is undertaking a problem in socioliterary criticism.

II. DEFINITION OF THE PROBLEM CONCEPT

The *problem concept* as used in science may be defined briefly as the focusing of inquiry on a single question of more or less limited

scope. (See Chapter 1.) But this definition in itself is insufficient; it needs elaboration. Exactly what constitutes a *problem?* Just what is the nature of scientific *inquiry?* The American philosopher John Dewey has made a valuable contribution to the clarification of the problem concept. He defines inquiry as "the directed or controlled transformation of an indeterminate situation into a determinately unified one."[1] The "indeterminate situation" with which inquiry begins is characterized as "not only 'open' to inquiry" but "open in the sense that its constituents do not hang together." Indeterminate situations are further described as "disturbed, ambiguous, confused, full of conflicting tendencies, obscure." Inquiry does not actually get under way, however, until the situation is recognized as indeterminate, or *problematic.* The task of the scientist is to recognize the situation as problematic and to define the problem.

A. The Problem as the Starting Point of Inquiry

It is a familiar and significant saying that a problem well put is half-solved. To find out *what* the problem and problems are which a problematic situation presents to be inquired into, is to be well along in inquiry. To mistake the problem involved is to cause subsequent inquiry to be irrelevant or to go astray. Without a problem, there is blind groping in the dark. The way in which the problem is conceived decides what specific suggestions are entertained and which are dismissed; what data are selected and which rejected; it is the criterion for relevancy and irrelevancy of hypotheses and conceptual structures.[2]

By contrast with the indeterminate situation with which inquiry begins, the determinate situation with which it ends—the "outcome of inquiry"—is described as "a closed and, as it were, finished situation or 'universe of experience.'" The chemist who seeks to synthesize an organic compound, the public health worker who inquires why tooth decay is more prevalent in one section of the country than in another, the paleontologist who studies fossils in an effort to determine more accurately the age of man—all are engaged in transforming an indeterminate into a more nearly determinate situation.

[1] John Dewey, *Logic: The Theory of Inquiry,* New York, Henry Holt and Company, 1938, p. 117.

[2] *Ibid.,* p. 108.

A particularly valuable feature of Dewey's definition is that it does not promise too much. The investigator may on occasion be satisfied if his inquiry has served to advance even slightly our state of knowledge, to leave an indeterminate situation somewhat less indeterminate. The sole purpose of some preliminary inquiries may be to define the area to be investigated and to chart the difficulties involved. Nor is the usefulness of Dewey's definition confined to natural science. Indeed it may be extended to illuminate all areas of research and to provide a technique for a rational attack on social and economic problems.

B. The Problem, the Hypothesis, and the Thesis

An understanding of the term *problem* involves a recognition of its relationship to two other terms—hypothesis and thesis. *Hypothesis* is best understood by going back to its derivation. It is from a Greek verb meaning "to place under." A hypothesis, then, is a theory or explanation "placed under" the known facts of the problem to account for and explain them. The hypothesis may then be tested by experiment. If it does not meet the test, it is re-examined. If established by sufficient testing, it becomes one of the accepted generalizations of science. The scientist's use of the hypothesis in solving a problem is admirably illustrated by Claude Bernard's work on carbon monoxide poisoning. (See Appendix A, p. 376.)

The term *thesis* has come down to us from the medieval university in which the candidate for the degree of doctor of philosophy was expected to defend his thesis or conclusion against all comers. The defense was purely verbal and consisted of references to established authority; it had little in common with the reference to fact and experiment of modern science. Yet we still use the term *thesis* to represent the solution to a problem, or partial solution, which is reached at the close of an investigation. In modern times, however, the emphasis has shifted from the defense of the thesis to the satisfactory working out of the problem. The inexperienced student often adds to his difficulties in writing a research paper by promising "to prove" something. Rather he should begin by perceiving a problem and undertaking to investigate it.

III. TYPES OF PROBLEMS

The only limit to the application of the problem concept as Dewey has defined it is the number of indeterminate situations which can be made more determinate by inquiry. It must be understood, however, that the problems in different disciplines are inherently different, as are the methods of analyzing and investigating them. Problems in chemistry, biology, physics, psychology, sociology—all have their special characteristics, and it would be folly to treat them as if they were alike. Regardless of the subject matter, however, a distinction should be drawn between *problems of fact, problems of value,* and *problems of means.*

A. Problems of Fact

The term *problem of fact* is used here to cover both individual facts—verifiable observations—and the relationships between facts without which the individual facts would have little significance. The concern of pure science, which seeks new knowledge for its own sake regardless of its potential usefulness,[3] is with problems of fact. Whether the earth is flat or round, whether a heavier body falls more rapidly than a lighter one, whether the center of the emotions is in the heart or elsewhere in the body, whether bacteria generate spontaneously or by reproducing themselves—all these are problems of fact which have been solved.

The almost fanatical persistence with which individuals will pursue the solution of a baffling problem of fact is apparent in the history of the attempts to express mathematically the value of π, the ratio of a circle's circumference to its diameter. The problem in one form has been traced to a papyrus of about 1700 B.C. By the second century A.D., Ptolemy, an Alexandrian mathematician, had achieved a value equivalent to 3.1417, which represents an error of about twenty-five parts per million. Little work was done on the problem in the western world during the Middle Ages, but at the time of the Renaissance the search began again. By 1948 collaborating British and American mathematicians achieved a value which cross-checked to 808 decimal points. In 1949 the computing machine ENIAC was set to work on

[3] It has, of course, been shown many times that knowledge sought originally for its own sake frequently proves useful later. See Appendix A, p. 379.

the value of π. According to N. T. Gridgeman's account, "Four operators worked eight-hour shifts, night and day, putting in a total of seventy man-hours, and emerged, pale-eyed but happy, with π to an elaborately checked 2035D [decimals]." [4]

B. Problems of Value

Where the problem of fact involves a question of what occurs, how it occurs, perhaps why it occurs, the *problem of value* involves the question of what is to be preferred or how highly something should be rated. "The characteristic of a problem of value," in the words of F. S. C. Northrop, "is that, in part at least, it raises a question concerning what ought to be, rather than what is, the case." [5]

Many problems of value are closely related to problems of fact. In these problems of value, judgment is rendered by reference to an established objective standard of values, such as a rating scale or a monetary standard. Typical of such problems are the chemist's testing of a sample of water and the metallurgist's assaying of an ore. Some problems of value may be studied and a basis for action established by setting up *standards* or *criteria* appropriate to the particular problem. If a choice must be made, for example, between two types of automobile engines—the V-8 and the Straight-8—specific questions must be answered before a decision can be reached. The investigator may ask which type of engine has greater power, which operates more economically, which is easier to maintain, which is more compact. These questions must be answered by reference to arbitrary production and performance standards.

In contrast to problems of value which are referable to objective standards, there are those which are referable only to personal or subjective standards. These problems are specifically the concern of philosophy, ethics, and religion, subjects that are rarely viewed with detachment. The scientist can contribute to their discussion, but not in the impersonal, objective spirit with which he attacks a problem of fact. This distinction is illustrated by the following passage in which an embryologist writes of the personal value which he as an individual attaches to the study of embryology.

[4] N. T. Gridgeman, "Circumetrics," *The Scientific Monthly*, 77:33, July 1953.
[5] F. S. C. Northrop, *The Logic of the Sciences and the Humanities*, New York, The Macmillan Company, 1947, p. 20.

> I hope that the human being whose biography during the first weeks of life is being sketched herewith, is already something more to the reader than a diagram in a book. This is your history I am telling and mine, and that of my own child and of yours. Here in the laboratory we can of course study and depict for you only those whose lives have been interrupted, and yet our experience trains us to think even of them as witnesses of life and growth. They never seem to us static or defunct. I have heard an embryologist who thought himself unsentimental and impersonal talk affectionately of a handsome three-weeks embryo as "he"; and speaking for myself, I seldom sit at the microscope to study one of these individuals we call "specimens" without the thought that here is one who but for the turn of circumstance would have taken his place in the army of the living. A microscope slide, says Professor W. B. Cannon, is a frozen moment in the flux of life.[6]

A problem of value that lacks a tangible referent does not lend itself to scientific inquiry, nor can it be definitely resolved, nor does it become the subject of scientific papers. Students who recognize problems of value as such will not unwisely attempt to write conclusive papers concerning controversial matters of political attitude, aesthetic appreciation, religious belief, or the like.

C. Technical Problems (Problems of Means)

The *technical problem* is concerned with the means by which a desired end is to be attained. Such problems are the province of applied science, the branch of science which applies the discoveries of pure science to the needs of man. Thus a technical problem combines elements of fact and value since through such problems the facts of science are focused on man's needs or wishes.

Technical problems arise, for example, when a newly discovered drug such as penicillin is to be manufactured on a commercial scale. The value of the drug has been tested. The basic chemical and physical facts are known. But means must be found for manufacturing this drug in quantity so that it will be available for general use. The technical problems connected with the early manufacture of penicillin were in fact so numerous that production appeared likely to be seriously hampered. According to its discoverer, Sir Alexander Fleming,

[6] George W. Corner, *Ourselves Unborn*, New Haven, Yale University Press, 1944, pp. 36-37.

it was the urgent demands of World War II that prompted scientists and drug manufacturers, with an unprecedented display of co-operation on an international scale, to attack this problem of means so vigorously and solve it so soon.

At times, conditions may enable the observer to anticipate future problems of means. Fremont Rider has stated one such problem which is being created by the rapidly increasing demands on the capacity of American libraries.

> But, if the Yale Library does continue to grow, and to grow at a rate no whit greater than it has been steadily growing through its more than two centuries of past existence, if it continues to grow at a rate no greater than the most conservative rate at which all our other American colleges and universities have grown ever since they started, and are now growing, then, by a series of further successive doublings, the Yale Library will, in 2040, have approximately 200,000,000 volumes, which will occupy over 6,000 miles of shelves. Its card catalog files—if it then has a card catalog—will consist of nearly three-quarters of a million catalog drawers, which will of themselves occupy not less than eight acres of floor space. New material will be coming in to it at the rate of 12,000,000 volumes a year; and the cataloging of this new material will require a cataloging staff of over six thousand persons.[7]

All laboratory workers know that every scientific investigation involves subsidiary technical problems, such as the finding of suitable experimental animals or the construction of apparatus. Moreover, every time a discovery is made, every time a major problem is solved, new problems are disclosed. Smallwood has noted how the new world uncovered by the microscope led to a need for new means of description and measurement.

> The microscope was well understood by the beginning of the nineteenth century, but naturalists had to create new standards of description when they began to use it. Old words were employed, but they must convey new meanings. A device had to be found for measuring the myriads of living creatures in every drop of water. Explanations were demanded for the phenomena revealed. Even the old hypothesis of spontaneous generation had to be revived, because without it all attempts to unravel the life cycle of microscopic creatures seemed vain. With so much adjustment to be made, it is not surprising that the

[7] Fremont Rider, *The Scholar and the Future of the Research Library*, New York, Hadham Press, 1944, pp. 11-12.

microscope did not come into general use in the laboratories of the universities before 1880.[8]

On the other hand, as the Spanish neurologist Ramón y Cajal pointed out in his autobiography, a technical discovery may open the way for the working out of problems hitherto considered obscure or insoluble. (See Appendix A, p. 387.) One remarkably fruitful discovery is that of the principle of ion exchange. Though this principle has been known for about a century, it has been extensively applied only since 1910. At the present time, ion exchange is being employed in a great variety of processes, including the recovery of metals from solutions, the refining of hydrocarbons, and the desalting of sea water for drinking use by fliers forced down at sea.

From the foregoing discussion of problems of fact, problems of value, and problems of means, it is evident that the interrelationship of these problems is complex. This interrelationship is illustrated by a catastrophe that occurred in the building of the [illegible] Quebec Bridge. This bridge over the St. Lawrence River was being built according to the cantilever plan, in which projecting arms meet or are joined in mid-air between piers. As one arm was nearing mid-channel, the entire structure collapsed, carrying eighty-two bridge men down with the wreckage.

> The investigations following the disaster revealed that the collapse was caused by the buckling of a compression member, due to inadequate lacing. Previously accepted empirical rules for the design of sections and details of compression members, tried and tested for smaller members, had betrayed the designer when they were applied to compression members of larger and unprecedented dimensions. As a result of the large-scale experiments and studies that followed, the design and detailing of large compression members were brought to a scientific basis. In addition, attention was now directed to the proper design and construction of the joints between compression members, and to the analysis and elimination of "secondary" stresses produced in truss members by their deformations. The Quebec disaster of 1907, more than any other occurrence in the evolution of bridgebuilding, revolutionized the art by bringing it to a new high level of scientific analysis and design.[9]

[8] William Martin Smallwood, *Natural History and the American Mind*, New York, Columbia University Press, 1941, p. 195.

[9] David B. Steinman and Sara Ruth Watson, *Bridges and Their Builders*, New York, G. P. Putnam's Sons, 1941, pp. 305-06.

In this instance the central problem of means was not solved until a dramatic infringement on the value attached to human life forced a review and further investigation of basic problems of fact.

IV. SETTING UP A PROBLEM

Finding a problem[10] suitable for laboratory research demands knowledge of a different order from that required for perceiving a problem suitable for a research paper. Nevertheless, if the writer is to be successful in finding problems, he must have the same spirit of inquiry that motivates the laboratory research worker.

A. Perception and Formulation of the Problem

In the following subsections of this chapter, means for finding problems for research papers are suggested. These suggestions are not intended as logical formulas but as exploratory devices which have proved useful to students.

1. *Observation*

The traditional source of a problem is an observation of a phenomenon which is not satisfactorily accounted for by existing knowledge. Such classic examples of problem-finding as Newton and the apple, Watts and the teakettle, and Columbus and the ships which disappeared beneath the horizon have become legendary. James B. Conant has cited "a nineteenth-century episode which illustrates how well-planned experiments may be used to follow up an observation."

> The story is familiar to all scientists, though perhaps it is not generally known that before Roentgen announced his discovery several other investigators noticed the fogging of photographic plates near an electric discharge tube. Roentgen followed up his observation; the others did not. But the clue from which Roentgen worked can hardly be considered a mere happy accident. For Roentgen was studying the stream of electrons (they were then called simply cathode rays) which can pass through a thin window in an electric discharge tube. He was aware that these rays would cause fluorescence of certain substances. He consequently had at hand a screen coated with such a substance and observed that it shone even when it lay at some distance from the tube. Following up this observation Roentgen quickly demon-

[10] The expression *finding a problem* is used here to mean not only perceiving or identifying a problem but seeking actively for one, as most research workers are at times obliged to do.

strated that some sort of radiation which passed through not only glass but opaque substances was responsible for the effect. From then on he was able to devise better methods of producing these rays and thus introduced a revolutionary technique.[11]

Unfortunately many students lack the questioning attitude which serves the scientist so well and tend to accept without question much that they read, hear, or see. Some students, however, through their own practical experience, become aware of problems which, though not true research problems, may serve as points of departure for undergraduate research papers. Yet problems within the range of the undergraduate are seldom research problems in a strict sense because, although the problem may be new to the student and he may have a genuinely fresh approach to it, the study is not designed to add consequentially to the total of human knowledge. One student, for example, who was employed by a firm specializing in gas heating installations found a suitable topic for a paper through his interest in the relationship between city building codes and the use of safety devices on gas heating equipment. Another student during his service in the Navy had become aware of the practical problems presented by the corrosion of metals and wrote his research paper about recent research studies dealing with the factors affecting corrosion and with newly developed methods of corrosion control.

The student who, while he reads, is sensitive to allusions and to the implications of statements will often see opportunities for research of which the less perceptive student will be unaware. For instance, references to the strategic theories of the late Admiral A. T. Mahan directed a naval science student to a research topic—the relevance of Mahan's theories to certain situations in recent warfare. Again, a statement that curare, used by South American Indians as an arrow poison, had been utilized in physiology and medicine aroused the curiosity of another student and resulted in his writing on the use of curare as an adjunct in anaesthesia. Another student's interest was turned to ornithology, in which many phenomena, as he discovered in his reading, have never been satisfactorily explained. In introducing the paper which grew out of this interest, the writer stated the problem as follows:

[11] James B. Conant, *Science and Common Sense*, New Haven, Yale University Press, 1951, p. 115.

For many years ornithologists recorded occasional observations of a peculiar phase of bird behavior without recognizing the fact that it was a definite habit of birds. It was not until 1935 that this type of behavior was determined to be a specific habit of birds and the German equivalent of the English term "anting" was proposed by Stresemann as a term to describe it. The term refers to the application by birds of any object, other than the oil of the uropygial gland, to the feathers with the bill through a type of preening action, or through "bathing" or dusting in various substances. The objects used in anting may be one of a number of various items, but are usually ants of non-stinging species, hence the name. Since the recognition of anting as a definite phase of bird behavior, considerable study has been undertaken in order to ascertain the cause of this habit. Although several theories have been advanced, none has proved completely satisfactory, the actual cause still remaining in doubt. The problem of determination of the motivation resulting in anting in birds is the basis for this paper.

2. *Intersecting Interests*

A method helpful to many students is that of taking two lines of interest and searching for a problem where these lines intersect. Such an intersection of interests is a frequent source of published research. For instance, Robert S. Harper's *Lincoln and the Press*, Don C. Seitz's *Lincoln the Politician*, and W. B. Hesseltine's *Lincoln and the War Governors* have all been built on a connection between Lincoln and a special interest of the authors. A stimulating historical dissertation, Richard Hofstadter's *Social Darwinism in American Thought*, developed out of an inquiry by Hofstadter into the use of phrases of Darwin and later evolutionists in the attempt to justify the exploitive character of American business during the latter part of the nineteenth century. *Ciba Symposia* once published as parallel articles "Monsters in Nature" and "Monsters in Art." [12] Here, two entirely different lines of interest—that of an embryologist and that of a professor of art—intersect "monsters."

Similarly, students may have interests which, if extended to the

[12] Viktor Hamburger, "Monsters in Nature"; Wolfgang Born, "Monsters in Art," *Ciba Symposia*, Ciba Pharmaceutical Products, Inc., Summit, N. J., 9:666-96, August-September, 1947.

point where they intersect with the subject matter of a course, will yield topics for research papers. A premedical student once wrote a successful paper based on an interest he had developed while working as a swimming instructor in the city pools. The student decided to look into the question of whether the swimming pool is a serious factor in the transmission of disease. This was his preliminary statement of his problem:

> People swim for two reasons, either for sport or for their health. However, every swimmer should answer the following question for his own sense of well being: "Will the physical and mental benefits I can obtain from swimming justify exposing myself to some contagious disease which I might contract at the pool?" Moreover, parents whose children clamor to go swimming wish to know the risk of contagion involved. What has been done to inform such people as to an individual's chance of contracting some infection at the swimming pool?

Because this student defined his problem carefully, he was able to arrange his material effectively and in the end to arrive at definite conclusions.

3. *Problem Patterns*

Certain problem patterns [13] are recurrent. Thoughtful comparisons, to name one recurring pattern, will bring out new ideas and new relationships. A student interested in political science found a subject for comparison in three novels dealing with the career of a demagogue: *Number One* by John Dos Passos, *A Lion Is in the Streets* by Adriá Locke Langley, and *All the King's Men* by Robert Penn Warren. He compared the novels with reference to five points: the careers of the central figures, resemblances to the career of the late Huey Long, the demagogue's personality and its appeal to the voters, the demagogue's retinue or entourage, and the viewpoint of the authors. The subjects compared—in this case the various interpretations of the demagogic character—have enough in common to justify the comparison and have variation enough to make it illuminating.

Another problem pattern is that of taking a single factor and trac-

[13] The term *pattern* is used here not in the sense of a model but in the sense of an orderly or logical arrangement of structure or activity.

ing it through different situations. An investigation of the expression of a certain prejudice in different environments would be a study of this type. A variation of this problem pattern is the "case study method" as used in the social sciences. A thorough study and analysis of a single representative instance of any phenomenon may help to clarify the entire subject. Some case studies have become famous, as did Morton Prince's study of the multiple personality which he called "Sally" and "Miss Beauchamp." Prince's study of the case led him to the conclusion that the repression of early conflicts had, in combination with other factors, resulted in a dissociated personality.[14]

4. *Time and Place*

Among the limits which may establish the boundaries of problems, time and place are prominent. Events or circumstances may create new problems or disclose problems hitherto unperceived. The Korean conflict, for example, brought many changes in international outlook and policy, any one of which might repay investigation. The discovery of the Boswell papers in Malahide Castle outdated much that had been written about James Boswell, opening the way for revisionary studies. When a 120-pound coelacanth—believed to be of a species that formed a linkage between fish and land animals—was caught west of Madagascar in the winter of 1952, zoologists had the opportunity to study a species thought, until 1938, to have been extinct for 50,000,000 years. Some changes brought about by time can, of course, be anticipated. Astronomers plan years in advance to utilize the predictable opportunities for observation afforded by eclipses and other recurrent astronomical phenomena.

In applied science, conditions changing with time are constantly pushing new problems into the foreground. The gain in longevity has advanced a new branch of medical science—geriatrics, or the care of the aged. The heavy defense production of jet planes has led to organized research on the problem of industrial deafness. This problem had been known to exist almost since the beginning of the industrial revolution, but little was done about it. Indeed, "weaver's ear" was regarded as "a badge of honor, indicating long service at

[14] Morton Prince, *Clinical and Experimental Studies in Personality*, Cambridge, Mass., Sci-Art Publishers, 1939, pp. 227-28.

the trade." [15] Now the problem is the subject of study under auspices of the Office of Naval Research.

The student who keeps up with current scientific news cannot fail to find research paper topics which are fresh because they are timely. Among the many topics which have been in the news in recent years are motion sickness, the fluoridation of drinking water, and the use of chlorophyll as a deodorant. The writer who chooses current topics of this sort has a relatively rich field since there has been little time or opportunity for a consideration of all the possible problems involved.

An appreciation of his environment likewise opens up many research problems for the student. The student of architectural history may profitably examine architectural monuments of his own locality; the student of political science may study local government agencies; the student of language may analyze characteristic local speech forms. Probably few have exploited the possibilities of a single locality as a source of problems as thoroughly as did the Lynds in *Middletown.*[16] This study, described as "a pioneer attempt to deal with a sample American community after the manner of social anthropology," presented a full account of a community of 30,000 people during the period from 1890 to 1925—its history, its conditions of employment, its homes, its schools, and its leisure, religious, and community activities. Indeed, *Middletown* has become the archetype of similar subsequent studies in the social sciences.

B. Limitation of the Problem

The term *problem,* as has been implied, denotes not only an inquiry but the specific portion of an inquiry which can be undertaken with hope of success by a single investigator or group of investigators in a single investigation. Knowledge may be compared to an ever-widening circle. As the circle widens, each segment of it becomes familiar to a smaller and smaller group of specialists. The more specialized knowledge a research worker has, the more exactly he should be able to conceive and formulate a problem. Certainly no one can formulate a problem intelligently in a field with which he is un-

[15] *Science News Letter,* 59:37, January 20, 1951.

[16] Robert S. Lynd and Helen Merrell Lynd, *Middletown: A Study in Contemporary American Culture,* New York, Harcourt, Brace and Company, 1929.

familiar. The exactness with which problems can be formulated, however, varies with the extent to which an area has been explored. In new fields of investigation, initial problems are sometimes tentative and exploratory. Even in a familiar field a preliminary period of reading or experiment followed by reflection is needed before a problem can be cast in final form.

If a problem has been well conceived at the outset of an investigation, little further limitation may be needed. The writer may find certain means of limitation—more or less artificial or arbitrary—a help in reducing his problem to manageable proportions. Not many students are as misguided as the one who suggested writing a research paper on "Life and Science"; most students, however, will find it necessary to undertake the disciplinary process of placing well-defined limits on the original concept of a problem. Among these limits are restrictions of time and place, restriction to fewer persons or groups, selection of a smaller category, and division of the original question. S. C. Ball's report *Fall Bird Migration on the Gaspé Peninsula* represents a limitation in time to the fall, in place to the Gaspé Peninsula, categorically to birds, and analytically to migration. Similar boundaries may be used to limit a variety of problems in applied science. For example, the general problem of tobacco mosaic—a virus disease attacking tobacco—might, for purposes of investigation, be limited in place to one locality, in time to the current growing season, and categorically to the effects of a specific method of control.

C. Evaluation of the Problem

To rule out problems which will not justify the expenditure of time and energy, the student should, during the process of formulating and defining his problem, use four questions as criteria to evaluate it.

1. Can the problem be put in question form? Every idle question does not constitute a problem, but every true problem can be stated in question form. Often this interrogative form will help to reveal weaknesses or inconsistencies.

2. Is the problem sufficiently limited? A serious study represents a deep probing of a limited area, not a superficial ploughing of a large surface.

3. Are the necessary primary sources or technical means of ob-

taining information available? This is a practical question and an important one. Indeed, in some instances research opportunities actually arise because of the availability of sources.

4. Will the findings have significance if the problem is satisfactorily resolved? To be significant a problem need not be of great magnitude. No problem exists in isolation, and the significance of a problem often derives from its relationship to the whole area of inquiry of which it is a part. The solution of a seemingly insignificant problem may supply a needed link in a chain of evidence, or the solution of a problem may be important largely because it opens up new avenues of investigation. Failure of the public to understand these complex relationships leads to much of the criticism concerning the apparently trivial nature of topics chosen for research.

When the student has found a problem which satisfies these criteria, he is ready for the next stage of his work, that is, for collecting data pertinent to his problem. (See Chapter 4.)

Some of the problems which will engage the attention of the student will doubtless seem too earth-bound to be described as "a springboard for a leap into the unknown." Nevertheless, an attack on even these lesser problems will afford an insight into that scientific tradition which leads the scientist to regard a problem as a challenge.

STUDY SUGGESTIONS

1. What are some of the major scientific problems which have been under investigation during the past half century? In each instance name the scientist or scientists who have been chiefly identified with the problem. Locate in the library some of the original reports concerned with one of the problems. Explain the difference between the general problem under investigation and the specific problem on which an individual experiment was based.
2. Douglas Bush tells in *Science and English Poetry* of a graduate student who proposed doing a thesis on the influence of the eighteenth century on the nineteenth. What characteristic of a research problem had this student overlooked?
3. Which of the following topics would, in your opinion, lend themselves to the setting up of library research problems? List the criteria by which you made your selection: (a) a comparison between the work of Newton and that of Einstein, (b) the cure of cancer, (c) recent work on antimitotic agents, (d) famous bridges of the world, (e) the

taxonomy of the fossil *Receptaculites oweni*, popularly known as the "sunflower coral," (f) the origin and influence of the phlogiston theory, (g) the erosion of arable land, (h) luminescence in fishes.

4. Could any of the rejected topics in the preceding exercise be limited effectively by applying the suggestions in Section IV of the foregoing chapter?
5. Prepare a list of problems which are of particular concern to your locality, institution, or industry.
6. Can you classify the problems which you listed in answer to Exercise 5 as problems of *fact*, *means*, or *value?* To what extent are these problems combinations of more specific problems of all three types?
7. Comment on the different ways in which the word *problem* is used in the excerpts given below from the *Scientific American*, 181(4), October 1949.

   ". . . a problem that we had first tackled 12 years ago but had been solved only in the last few months"; "problems which will challenge science for a long time to come"; "the world's increasingly acute food problem"; "technological problems and unpredictable economic factors"; "one of the most difficult and fascinating problems in biological oceanography"; "the problem, then, is to find some method of separating the rates of growth and death and measuring them independently"; "a central problem of biology: the problem of the cause of old age"; "the analysis of leaf shape may become a problem of great importance in biology"; "the problems of clinical tuberculosis"; "the biological aspects of the problem"; "when we decided to attack this problem, a technical difficulty at once presented itself"; "the answer to our problem came from chemical technology"; "a more rapid investigation of our central problem: the mechanism of virulence."

8. List the accepted denotations of the word *problem* and distinguish among them. Which of these denotations represents most closely the scientific concept of the *problem?*
9. Discuss the extent to which the scientist may properly concern himself with the uses or applications which are made of his contributions to knowledge.

CHAPTER 3 DEFINITION AND TERMINOLOGY

A word is not a crystal, transparent and unchanged, it is the skin of a living thought and may vary greatly in color and content according to the circumstances and the time in which it is used. OLIVER WENDELL HOLMES, JR., Towne *v.* Eisner, 245 U.S. 425.

Exactness cannot be established in the arguments unless it is first introduced into the definitions. HENRI POINCARÉ, Science and Method.

I. SCIENTIFIC TERMINOLOGY AND DEFINITION

To the scientist the *terminology* of his subject is inseparable from the subject itself. It is an indispensable means of expressing and transmitting the observations, methods, laws, and theories which constitute a science as a branch of knowledge. The terminology of a

science consists of the words or expressions—that is, the terms—used in a special significance in that science, so defined in its literature, and so understood by its adherents. Thus the terms *inertia* for the physicist, *catalyst* for the chemist, *homology* for the biologist, *fault* for the geologist, *unit rule* for the political scientist, as well as thousands of other terms in the technical dictionaries, have significance which is comprehended only partially by the general public.

Science, looked at in this way, has been described as a process of applying names to things. The accumulation of an adequate terminology is an important part of the growth of science. Every science has in a sense its own language, and learning that language is a part of the student's apprenticeship to the science. If the language of science is to be adequate for transmitting our scientific heritage, the relationship between scientific terms and the meanings they represent must be maintained by a continuous process of definition.

A. A Science and Its Terminology

For purposes of record and terminology, scientists must have ways of designating vast numbers of phenomena and of expressing vast numbers of fine distinctions. The chemist must be able to differentiate among thousands of complex chemical compounds, the botanist among plants, the zoologist among forms of animal life. In many sciences an important branch of terminology is *nomenclature* (by derivation, calling by name) or the system of names used in classifying the objects of study. In addition to the verbal terminology and accepted abbreviations, the nonverbal symbols, such as the symbols of chemical formulas, of genetic tables, and of mathematical equations, make up the language of a science.

One advantage of the specialized language of science is the condensation of systematized knowledge it achieves. When the Swiss naturalist Abraham Trembley in 1744 published his treatise on freshwater polyps, he was obliged to designate them as *polyps with arms in the form of horns*. Such cumbersome descriptive designations were no longer necessary after 1758 when the Swedish botanist Carolus Linnaeus introduced his binomial system of nomenclature into the tenth edition of *Systema Naturae*. According to Linnaeus' system, any plant or animal may be designated by a double Latin name, the first part denoting the genus and the second part the species. For

example, Linnaeus' generic name for the cat family was Felis; the lion became *Felis leo;* the tiger, *Felis tigris.*[1] Some technical terms may seem long and cumbersome; yet the scientist can achieve great economy of expression through their use. For example, the term *radioactivity* is defined by Webster's as "the property or process whereby certain elements or isotopes (notably, radium, uranium, thorium, and their products), whether free or combined, spontaneously emit particles and/or rays by the disintegration of the nuclei of their atoms." Nonverbal symbols—NaCl for sodium chloride, ∞ for infinity, μ for micron—afford still more compressed means of expression.

A further distinguishing characteristic of scientific language is its precision. Of all the languages of science, the language of mathematics is generally conceded to be the most exact. It is doubtless impossible for all sciences to attain the exactness of pure mathematics, but scientists in all fields are constantly striving to improve their terminology. Expansion of the existing terminology to cover new knowledge becomes a problem in a rapidly growing science. Furthermore, scientists within a field may differ as to the meaning and application of terms. Such questions are sometimes referred to special committees of scientific organizations and to sessions of scientific conferences.

B. Scientific Terminology and Everyday English

Some problems of scientific terminology are complicated by the fact that the language of science and everyday English overlap, and as a result an interchange of expressions between the two is constantly taking place. Numerous scientific terms are common words which have been given a special scientific significance. The word *work,* for example, means to most people some sort of labor, either mental or physical. As used in physics, the term *work* becomes a measurable quantity when defined as follows: The work done on a body by a force is the product of the force and the distance the body moves in the direction of the force. By contrast, a term which is primarily scientific may be metaphorically used in a more general sense,

[1] For a discussion of the use of the Linnaean system and the designation of subspecies see John N. Hough, *Scientific Terminology,* New York, Rinehart and Company, 1953, pp. 195-210.

as when one speaks of a person going off on a tangent or of two parallel lines of thought.

When the scientific and popular uses of a word are sufficiently distinct, little confusion arises. But when the public persistently uses a scientific term erroneously in what it thinks is the scientific sense, the value of the term is impaired. In one instance a specialist has suggested trading terms with the public. The *Science News Letter* for May 19, 1951, reports a proposal for substituting *mental disorder* (*mild, moderate, or severe*) for *neurosis, psychoneurosis,* or *psychosis,* on the grounds that the latter terms have become so much a part of household language that they have lost their precise meanings. This wearing away of the precise meanings of terms—a sort of linguistic erosion—may be hastened by the presence of emotional attitudes. The word *neurotic* has become in popular use little more than an uncomplimentary epithet. One person may accuse another of having *complexes* without any knowledge of what a complex is. *Moron,* which began as a designation of a degree of feeble-mindedness, has become popularly a vague term of derision.

It is probably fortunate, however, that scientific terminology is a part of the general language rather than independent of it. If no general linguistic ground existed, specialists could communicate only with each other—not with other scientists or with the public. Nevertheless, even a brief consideration of the relationships between scientific terminology and everyday English makes it evident that an attempt to set up an exact terminology within a language is somewhat opposed to the natural tendencies of words to shift their meanings in use. These tendencies have been made the subject of study in the branch of linguistic science known as *semantics*—the systematic study of meanings. Some of the semantic considerations which have a bearing on scientific terminology and its definition will be discussed in Section II of this chapter as a background to the presentation of the process of definition in Section III.

II. THE CONTRIBUTION OF SEMANTICS

It is a principle of semantics that a word has no intrinsic meaning apart from its use. In the languages of the world many different words represent the idea of a house; the meaning of each word lies

not in the word itself, but in the association between the word as a symbol and what it stands for.

A. The Significance of Context

A corollary of this principle is that a word has only an artificial, dictionary existence apart from the *context* in which it is used. In fact, the verbal context determines the sense in which we understand a word. The word *style,* for example, occurs in these four phrases—a writer's style (manner of writing), the latest style (fashion), an architectural style (mode of execution), and typographical style (form and arrangement)—but in each of the phrases the word has a different meaning. A second corollary is that the meaning of a word, the sense in which it is understood, is subject to change as the conditions of its use change. The word *very,* for instance, was historically an adjective meaning *true,* and was a word of some force. Through long use it has become so weakened that it is now a mild intensive with so little force that its free use is frowned on by experts in style. The dictionary does not determine what a word means; it only collates and records from a variety of contexts the different meanings in which a word has been used.

This variable relationship between a word and its meaning creates relatively little confusion as long as individuals trying to communicate with one another have similar associations with words, as do the members of the same social group. But when the interchange of words is between people of different backgrounds or different purposes—when the *social context* changes—misunderstandings arise. Different people may refer to the same object by different words. Conversely, the same word may mean different things to different groups. The name *worm snakes,* for example, has been applied to two entirely different groups of snakes. "This," it has been noted, "illustrates one of the grave defects of popular names—totally different animals in different parts of the country are often known by the same name, so that no one can be positive as to which animal is referred to." [2]

Virginia C. Gildersleeve has reported some of the language diffi-

[2] Karl P. Schmidt and D. Dwight Davis, *Field Book of Snakes of the United States and Canada,* New York, G. P. Putnam's Sons, 1941, p. 91.

culties encountered at the United Nations Conference on International Organization at San Francisco in June 1945.

> I am not dealing here with the difficulty caused by difference of language. Of course, the use of five different languages at the San Francisco Conference caused exasperating delays and considerable difficulty of understanding. What I am alluding to here is something much more profound. The same words mean different things to different peoples because they arouse in their minds different ideas, different backgrounds of circumstance and tradition, and different emotions. And often we do not realize this; we think we are agreeing. But we are not and, later, trouble ensues. Words have been not a medium of understanding, but a barrier to understanding.[3]

Students of semantics have held that no word can ever mean exactly the same thing to any two people. In the strictest sense this is true. Yet to accept the complete individualization of meaning would be a counsel of defeatism. The alternative is to work toward a common basis of understanding, difficult to achieve though it may be.

B. Words as Symbols

It is perhaps indicative of the complementary nature of science and poetry that, while the theory of both is concerned with the use of words as symbols, the word symbols of poetry are connotative and depend for their effect upon the associations of words, and the word symbols of science are denotative and depend for their effect upon the accuracy with which they represent a specific meaning. Semanticists have divided words as symbols into three groups according to the types of meanings they represent. The simplest group includes words which represent a specific referent or object referred to, something which can be perceived by the senses, such as a table, chair, and desk. The second group consists of words of action or feeling which can be dramatized (purchase) or indicated by pantomime (laughter). The third group includes words representing abstractions such as justice, freedom, and truth.

All scientific terms represent in some degree a generalized idea or *concept.* The term *tendon,* for example, does not represent any single tendon but a generalized idea of what a tendon is, derived from the

[3] Virginia C. Gildersleeve, "Intellectual Allergies," *The Saturday Review,* 33:5, December 16, 1950.

observation of many such structures. Some terms represent much more highly generalized or abstract concepts than others. The botanical term *leaf,* for example, though leaves are sometimes confused with petals or leaflets, is relatively concrete since large numbers of leaves can be assembled for observation and comparison. A term representing a process, such as *radiation,* can readily be made clearer by demonstration. At a higher level of abstraction are such terms as *heredity, environment, development,* and *relativity* which represent concepts which can be neither seen nor demonstrated. However, even these highly abstract concepts must be supported by verifiable observational or experimental data if they are to have scientific standing.

A further analysis of words as symbols shows that many words have only relative meaning. There is a vast difference between a small molecule, a small town, a small person, and a small planet. Louis N. Ridenour, writing of the hydrogen bomb, refers to "the old-fashioned atomic bomb." The application of relative terms should not be confused with that of terms indicating precise measurements. *Toxicity,* for instance, is a relative term, but can be made more precise by the determination of the *lethal dose* of a drug, or the amount which will cause death under certain specified conditions.

Words may be used to convey facts or to arouse emotions; however, they sometimes arouse emotions when we intend for them to convey facts. Semantic studies have shown that many words in popular use have descended to the present with a high emotional content and embody popular "myth" rather than scientific truth. Writing on "The Myth of Blood" M. F. Ashley Montagu goes so far as to say that "the meaning of most, if not of all words, is to some extent emotionally determined." Among words "distinguished by a high emotional and a low rational, or reasonable, quality" he has singled out *blood* for special study. Pointing out that hereditary characters are transmitted by the genes and not by the blood, he concludes, "What modern science has revealed about blood renders all such words as blood royal, half-blood, full-blood, blood relationship, and the others to which reference has been made utterly meaningless in point of fact, and dangerously meaningful in the superstitious social sense." [4]

[4] M. F. Ashley Montagu, "The Myth of Blood," *Psychiatry,* 6:15-19, February 1943.

In summary, semantic studies [5] of word meanings have shown that words as symbols are dependent on context and are frequently sources of misunderstanding and are subject to emotional associations. Hence, scientists and others who wish to use words for exact communication must not only define them but must also have in common with their readers a background of reading and experience.

III. THE PROCESS OF DEFINITION

The purpose of the scientific writer is not to fix permanently the meaning of terms. Such a freezing of terms would be impossible and to attempt it would have an inhibiting effect on scientific thought. Moreover, there is no justification for the inexcusable prolixity of the occasional writer or speaker who insists on elaborately defining commonplace and well-understood terms. But the scientific writer should make clear to the reader the sense in which he is using a term the meaning of which is likely to be misconstrued.

A. Words, Terms, and Concepts

Definition involves a distinction between words, terms, and concepts. *Term,* as used with reference to definition, is defined in *Webster's New Collegiate Dictionary* as "A word or expression having a precisely limited meaning . . . peculiar to a science, art, or the like; . . ." A single *word,* therefore, may embody many terms. The noun *block,* for example, represents about fourteen distinct meanings, ranging from the child's building block to the nerve block of medicine and the mental block of psychology. The word *featherbedding* as applied to labor practices is a metaphorical extension of its original meaning; beginning as railroad slang, it has become established as a distinct term in the discussion of labor relations. Many terms are combinations of words which, taken together, have a special meaning. The expression *take-home pay* originated when pay deductions became common. Familiar examples of combinations of words

[5] For books presenting different points of view concerning semantics see C. K. Ogden and I. A. Richards, *The Meaning of Meaning,* 8th ed., New York, Harcourt, Brace and Company, 1947; Alfred Korzybski, *Science and Sanity: an Introduction to Non-Aristotelian Systems and General Semantics,* Lancaster, Pa., Science Press Printing Company, 1933; Stuart Chase, *Power of Words,* New York, Harcourt, Brace and Company, 1954; S. I. Hayakawa, *Language in Thought and Action,* New York, Harcourt, Brace and Company, 1949.

used as terms in the sciences are *centrifugal force, natural selection, defense mechanism, surface tension,* and *capillary attraction.*

Terms represent *concepts,* or generalized ideas or principles, many of which have developed over a long period of time and have been extended with the growth of scientific knowledge. The astronomer, for example, has been obliged continually to expand his concept of the universe until now it must include the stars a billion light-years away which are visible through the most modern telescope. Even more startling is the growth in the biologist's concept of the cell. To the fully informed biologist the word no longer represents the simple walled unit of earlier biological thought, or even the more elaborate structure visible under the high-power microscope. It represents instead an intricate concept.

> Even from the incomplete account which has been given of the physico-chemical organisation of the cell it is clear that each particular region of the cell consists of a complex interlocking of very many simultaneously active physico-chemical systems. Each particular region of the cell has its properties defined by a vast group of variables, some of which are linked and some of which are independent. Our understanding of these is very far from complete. In some instances the necessary physics and chemistry is almost completely unknown. In very few instances are we able at present to deal quantitatively with these variables. When sufficient information is available to permit completely quantitative treatment, it is likely that the system will be so complex that it will be impossible to utilise this knowledge without the aid of electronic calculating machines.[6]

The knowledge that lies behind a term may thus be much too extensive to be encompassed in a definition that can include only the distinguishing features of the concept.

B. Adaptation of a Definition to Its Purpose

Approaches to the problem of definition have ranged historically from the classic formal definition to the operational definition favored by many modern scientists. A definition may range in length from the explanatory phrase which sometimes constitutes the informal definition to an extended definition of many pages. Occasionally the purpose of a paper is the development of a definition, and the entire

[6] J. F. Danielli, *Cell Physiology and Pharmacology,* Amsterdam, Elsevier Press, Inc., 1950, p. 23.

paper becomes an extended definition. A writer's purpose will determine which type of definition he will use.

1. The Formal Definition

The intent of definition is expressed in the derivation of the word, from *de* meaning about and *finis* meaning limit or end. The object of a definition is to locate the boundaries which limit the application of a term. The one-sentence formal definition is the classic basis of definition. This definition is formal because it follows a prescribed form: the *term* is first placed in the *class* to which it belongs; then it is distinguished from other members of that class by stating its distinctive characteristics, called the *differentiae* (singular, *differentia*). For example, one of the sciences has been defined by this statement: *botany* is the science which deals with plant life. Here *botany* is the term, *science* is the class, and the clause *which deals with plant life* constitutes the differentia.

The formal definition is not an arbitrary construction. It is a verbal counterpart of the classifying process which is basic in science. Thus in zoology the genus *Diadophis* includes groups of snakes (the class) characterized by a brightly colored ring on the neck (the differentia). Here the definition is simply a verbal expression of the criterion by which this group of snakes is distinguished. A thoroughly satisfactory definition should (1) include everything that the term covers, (2) exclude everything that the term does not cover.

In order to gain skill in formulating definitions it is good practice to try to define some familiar term. An immature attempt at defining *calipers* might be: calipers are something (class) you measure with (differentia). Obviously this is far from an adequate definition. The class is much too inclusive, and the definition fails to exclude rulers, tapes, protractors, and numerous other measuring devices. Other unsatisfactory classes may be offered—calipers are a tool (inaccurate), equipment (too broad), engineering instrument (too narrow) —until finally the class *instrument* is arrived at, and a second definition constructed: *calipers* are an instrument used for measuring in one dimension, such as length, thickness, or distance. This definition is better, but the differentiae are still not sufficient to exclude other measuring instruments. If the differentiae are extended to include the structure of the instrument as well as function, this difficulty is

overcome, and the following definition results: *calipers* (term) are an instrument (class) which has two legs or arms usually curved and fastened together with a rivet or screw or with a spring and pivot, and which is used for measuring in one dimension, such as length, thickness, or distance (differentiae).

The proper choice of a class is essential to successful definition. If the class is too broad, it imposes too great a burden on the differentiae; if the class is too narrow, it limits the definition beyond the intent of the writer. A concrete term is usually easier to classify than an abstract one—a hammer is a tool, a maple is a tree, a flute is a musical instrument. A commonplace thing may, however, be difficult to define. It is difficult, for example, to construct a definition of a *shirt* which will include all shirts and yet exclude blouses, coats, and sweaters. On a more erudite level, similar problems beset the scientist. In the *Field Book of Snakes*, the authors, curators of the Chicago Natural History Museum, observe that it is difficult to define the subject of their book.

> The snakes are so closely allied to the lizards and monitors that it is somewhat difficult to frame a formal definition that completely and readily distinguishes them. This difficulty rests primarily on the fact that many different types of lizards are limbless or nearly so. Snakes are distinguished from all lizards by the fact that the two halves of the lower jaw are separated, connected only by an elastic ligament; and the great majority of snakes are at once distinguished by their transverse ventral plates.
>
> Snakes may be defined as elongate, scaly reptiles without limbs or with the vestiges of hind limbs only, without movable eyelids, without ear-opening, with an elongate, deeply forked, and retractile tongue, with a transverse vent and paired organs of copulation, and with the two halves of the lower jaw independently movable, connected in front by an elastic ligament. Most snakes have straplike transverse scales, the *ventral plates*, extending from side to side on the undersurface of the body.[7]

Certain difficulties tend to recur in the process of framing formal definitions. These difficulties may be avoided by observing six basic principles.

1. A synonym, discussion, explanation, or description should not be substituted for the class and differentiae of a correctly framed

[7] Schmidt and Davis, *op. cit.*, pp. 17-18. Courtesy G. P. Putnam's Sons.

definition, though descriptive detail may form part of the differentiae. For example, *television* should not be defined by saying that it is a popular form of entertainment, that interest in it is increasing, that parents are showing concern because it is interfering with children's studies. These statements may be true, but they do nothing to define television; they do not even distinguish it from comic books or the movies; nor would the synonym *video* define television.

2. The wording of the term should not be repeated in the definition. For example, *sanitation* should not be defined as the employment of sanitary measures. Sanitation may be defined as the employment of measures (class) tending to preserve healthful conditions and to eliminate conditions injurious to health (differentiae). The one exception to this rule concerns a compound term only part of which requires definition. For example, a dry cell may be defined as a voltaic cell (class) whose contents are treated by the use of an absorbent so as to prevent their spilling (differentiae).

3. A definition should be stated in the positive, not the negative. To undertake to define the term *pistol* by saying that a pistol is not a rifle and not a shotgun gives no direct indication of what a pistol is. A pistol may be defined, however, by placing it in the class of firearms and then showing how it differs from other firearms. It is often necessary in a definition to show how the subject of the definition is unlike the things which most resemble it, but this does not justify predicating the entire definition in the negative.

4. The term should, whenever possible, be defined in words simpler than the term itself. If the concept to be defined is a difficult one, technical language may be needed to express it, but technicalities should not be introduced needlessly. Dr. Samuel Johnson, our first great dictionary maker, wrote the proverbial example of a violation of this precept when he defined a network as "any thing reticulated or decussated, at equal distances, with interstices between the intersections."

5. The definition should not show bias or reflect the personal opinions of the writer. Dr. Johnson violated this precept also in his definitions of *Tory* and *Whig*. Tory he defined as "one who adheres to the ancient constitution of the state, and the apostolical hierarchy of the church of England, opposed to a whig." Whig he defined as "the name of a faction."

The connotative, impressionistic, or epigrammatic definition is sometimes included in discussions of definition. An example is the definition attributed to G. K. Chesterton, "A classical novelist is a writer to whom one may pay a eulogy without having read any of his books." Delightful and penetrating as such epigrams may be, they are too subjective to be considered definitions in the scientific sense.

6. Equivalent or corresponding parts of the definition should be expressed in the same or parallel grammatical structure. The commonest violation of this rule is the linking of a noun with an adverbial "when" or "where" clause, as in writing "capillary attraction *is when* a liquid rises in a tube," or "intersection *is where* two lines cross."

The formal definition is the type usually used in textbooks, reference works, papers, and documents where conciseness is mandatory. The formal definition or an extension of it is also the type usually expected when definitions are called for in written or oral examinations.

2. The Operational Definition

The formal definition originated many years ago when the emphasis in the sciences was on the classification of natural phenomena. Though this process of classification is still going on, the emphasis has shifted to processes, experiments, and operations or procedures. In keeping with this new emphasis a type of definition has been developed—known as the *operational definition*—which limits the meaning of a term, not by means of classes and differentiae, but by an account of the activities or procedures which lead to the application of the term.

For example, *density* is not defined operationally by classifying it as a state or quality. The physicist may, however, define *density* operationally by saying that it is determined by calculating the ratio of the mass of a homogeneous portion of matter to its volume. The statistician may define *density of population* by saying that it can be estimated by counting the number of persons per square mile of area. The following excerpt offers further illustrations.

> An operational definition tells *what to do* to experience the thing defined. Asked to define the coefficient of friction, a physicist says something like this: "If a block of some material is dragged horizon-

> tally over a surface, the force necessary to drag it will, within limits, be proportional to the weight of the block. Thus the ratio of the dragging force to the weight is a constant quantity. This quantity is the coefficient of friction between the two surfaces." The physicist defines the term by telling *how to proceed* and *what to observe*. The operational definition of a particular dish, for example, is a recipe.[8]

One of the chief advocates of the operational definition, which has many supporters among scientists and semanticists, is the Nobel prize winner P. W. Bridgman, who asserts, "What a man means by a term is to be found by observing what he does with it, not by what he says about it." [9] And again, "The meanings of one's terms are to be found by an analysis of the operations which one performs in applying the term in concrete situations or in verifying the truth of statements or in finding the answers to questions." [10]

The operational definition need not, however, be regarded as a substitute for the formal definition. After all, definition is itself a concept, and the development of the theory of the operational definition has enlarged our concept of what a definition is and how one can be formulated. There are times when the definite form and compact structure of the formal definition make it the better choice. Certainly the operational definition should not be made an excuse for vague attempts at definition which leave the meaning of a term no clearer than before. If an operational definition is to be adequate, it must be as carefully constructed as a formal definition. A good way to re-examine a concept is to attempt to construct both a formal and an operational definition of the term which represents it.

3. The Informal Definition

The informal definition and the extended definition are not to be regarded as distinct types of basic definitions but as shortened or amplified versions of formal or operational definitions. The informal definition is a short statement or phrase inconspicuously introduced to recall or explain briefly the meaning of a term. Such definitions are much used in writing addressed to the general public rather than

[8] Anatol Rapoport, "What Is Semantics?" *American Scientist*, 40:128-29, January 1952.

[9] P. W. Bridgman, *Reflections of a Physicist*, New York, Philosophical Library, 1950, p. 5.

[10] *Ibid.*, Preface, p. *v*.

to the specialist. Experienced writers become adroit in providing definitions sufficient for the reader's immediate needs without pausing to introduce formal definitions. To illustrate the usefulness of informal definition an example has been chosen from each of the seven articles in the July 1949 issue of the *Scientific American.*

The word communication, in fact, will be used here in a very broad sense to include all of the procedures by which one mind can affect another.—Warren Weaver, "The Mathematics of Communication," p. 11.

The Pasteur treatment for rabies, a series of inoculations of rabbits' spinal cord tissue containing weakened rabies virus, was first used on a large scale at the end of the last century.—Elvin A. Kabat, "Allergic Mechanisms in Nervous Disease," p. 16.

The peculiar feature of the moon's physiognomy was its huge cup-like depressions, named "craters" from the Greek word for cup.—Ralph B. Baldwin, "The Craters of the Moon," p. 21.

While the name "pile" has commonly been used for all types of chain-reacting systems except bombs, "reactor" is now preferred as a more inclusive term, covering the newer types.—Leon Svirsky, "The Atomic Energy Commission," p. 32.

Nearly half of the hospital beds in the United States are occupied by patients suffering from mental illness, and about a third of these patients have a psychosis known as schizophrenia or dementia praecox. This is an all too common and serious form of insanity, affecting nearly one percent of the population. Brilliant people often develop it and are lost to society.—Hudson Hoagland, "Schizophrenia and Stress," p. 44.

Cuvier had devoted much time to the study of the more advanced vertebrate classes, but little had been done on the remains of fishes, although they are as numerous and as diversified in nature as all the rest of the backboned animals put together.—Alfred Sherwood Romer, "Louis Agassiz," p. 49.

Among the miscellany of creatures that inhabit the earth, whales possess a peculiar interest. Although they are air-breathing mammals, their highly specialized physiology permits them to remain under water for prolonged periods of time. Their great size is well known.—Cecil K. Drinker, "The Physiology of Whales," p. 52.

4. The Extended Definition

The statement that "behind words lies meaning and behind meaning lies life" can readily be applied to problems of definition in science. Behind the term lies the concept, the generalized idea which

the term represents, and behind the concept lie the phenomena of nature which generations of scientists have observed and experimented on in developing that concept. When a concept is complex or highly abstract, a short definition is adequate to summarize it or to identify it, but not to give the reader any real understanding of it. For this latter purpose a longer definition, the "extended definition," is needed. An extended definition may be in a measure creative, as when a writer coins a term to identify a developing concept, or when by the cogency of his summary and the breadth of his knowledge, he enriches a concept already known.[11]

a. Arrangement of an Extended Definition

The extended definition is frequently, though not necessarily, an elaboration of a formal definition. Unlike the formal definition, the extended definition does not have a rigid pattern. Its form develops from the nature of the concept and the nature of the writer's contribution to it. The arrangement of the extended definition is analogous to the arrangement of a paragraph, although the definition may at times extend far beyond a paragraph in length. The definition may, like a paragraph beginning with a topic sentence, open with a formal definition and then explain it, as in the following example.

> The tides are a response of the mobile waters of the ocean to the pull of the moon and the more distant sun. In theory, there is a gravitational attraction between every drop of sea water and even the outermost star of the universe. In practice, however, the pull of the remote stars is so slight as to be obliterated in the vaster movements by which the ocean yields to the moon and the sun. Anyone who has lived near tidewater knows that the moon, far more than the sun, controls the tides. He has noticed that, just as the moon rises later each day by fifty minutes, on the average, than the day before, so, in most places, the time of high tide is correspondingly later each day. And as the moon waxes and wanes in its monthly cycle, so the height of the tide varies. Twice each month, when the moon is a mere thread of silver in the sky, and again when it is full, we have the highest of the high tides, called the springs. At these times sun, moon, and earth are directly in line and the pull of the two heavenly bodies is added together to bring the water high on the beaches, and send its surf leaping upward against the sea cliffs, and draw a brimming tide

[11] William James' definition of "stream of consciousness" which is cited later in this section is an example of creative definition.

into the harbors so that the boats float high beside their wharfs. And twice each month, at the quarters of the moon, when sun, moon, and earth lie at the apexes of a triangle, and the pull of sun and moon are opposed, we have the least tides of the lunar month, called the neaps.[12]

Another arrangement possible in extended definition is that of William James' classic definition of "stream of consciousness," which begins by presenting an analysis of the author's observations and introduces the term itself as a climax. This arrangement is comparable to the inductive paragraph which begins by presenting particulars and concludes with a generalization.

Within each personal consciousness, thought is sensibly continuous. I can only define "continuous" as that which is without breach, crack, or division. The only breaches that can well be conceived to occur within the limits of a single mind would either be *interruptions, time-gaps* during which the consciousness went out; or they would be breaks in the content of the thought, so abrupt that what followed had no connection whatever with what went before. The proposition that consciousness feels continuous, means two things:

a. That even where there is a time-gap the consciousness after it feels as if it belonged together with the consciousness before it, as another part of the same self;

b. That the changes from one moment to another in the quality of the consciousness are never absolutely abrupt. . . .

Consciousness, then, does not appear to itself chopped up in bits. Such words as "chain" or "train" do not describe it fitly as it presents itself in the first instance. It is nothing jointed; it flows. A "river" or a "stream" are the metaphors by which it is most naturally described. *In talking of it hereafter, let us call it the stream of thought, of consciousness, or of subjective life.*[13]

A third arrangement is analogous to the paragraph which opens with the topic sentence, develops it, and repeats it in substance at the end. This is the pattern of James Harvey Robinson's well-known definition of "rationalizing." [14] Early in the definition he makes the statement that "most of our so-called reasoning consists in finding

[12] From *The Sea Around Us* by Rachel L. Carson, p. 152. Copyright 1950, 1951 by Rachel L. Carson. Reprinted by permission of Oxford University Press.

[13] William James, *Psychology*, New York, Henry Holt and Company, 1923, pp. 157-59.

[14] James Harvey Robinson, *The Mind in the Making*, New York, Harper & Brothers, 1921, pp. 40-44.

arguments for going on believing as we already do." After giving numerous illustrations to support this statement, he concludes with a formal definition: "Rationalizing is the self-exculpation which occurs when we feel ourselves, or our group, accused of misapprehension or error."

b. Methods of Developing a Definition

The means of explanation employed in an extended definition must depend on the writer's purpose in offering the definition and on the nature of the concept. Danielli's *analytical* definition of *narcosis* emphasizes the complexity of the reactions included under the term.

> Before proceeding in further detail, it will be as well to get some idea of what is referred to under the heading of narcosis. It is not a word with a single precise meaning. It includes such phenomena as the loss of consciousness, inhibition of a reflex, inhibition of the contractility of, say, heart muscle, inhibition of cell division, inhibition of ciliary movement, inhibition of respiration, etc. Usually a given narcotic substance will produce all these effects, but at different concentrations. . . . From the facts already considered it is improbable that all the narcotic actions of a given substance are produced by the same mechanism. Hence it does not follow that what is established for a narcotic in one connection is necessarily involved in any other action involving the same narcotic.[15]

The definition of *narcotic drugs* in the Uniform Narcotic Drug Act, which has been adopted by most of the states to supplement the Federal Harrison Anti-Narcotic Law, is entirely different since its purpose is to establish a basis for legal action. Provisions 11, 12, and 13 of the section *enumerating* narcotic drugs read:

> "Coca leaves" includes cocaine and any compound, manufacture, salt, derivative, mixture, or preparation of coca leaves, except derivatives of coca leaves which do not contain cocaine, ecgonine, or substances from which cocaine or ecgonine may be synthesized or made.
>
> "Opium" includes morphine, codeine, and heroin, and any compound, manufacture, salt, derivative, mixture, or preparation of opium, but does not include apomorphine or any of its salts.
>
> "Narcotic drugs" means coca leaves, and opium and every substance neither chemically nor physically distinguishable from them.[16]

[15] Danielli, *op. cit.*, pp. 97-99.

[16] Emanuel Hayt and Lillian R. Hayt, *Legal Guide for American Hospitals*, New York, Hospital Textbook Company, 1940, pp. 401-03; see also p. 360.

Since the essence of definition is *distinction*, an extended definition may be devoted to clarifying the distinction between concepts which are popularly confused. Lewis Mumford here distinguishes between a machine and a tool.

> The essential distinction between a machine and a tool lies in the degree of independence in the operation from the skill and motive power of the operator: the tool lends itself to manipulation, the machine to automatic action. The degree of complexity is unimportant: for, using the tool, the human hand and eye perform complicated actions which are the equivalent, in function, of a well developed machine; while, on the other hand, there are highly effective machines, like the drop hammer, which do very simple tasks, with the aid of a relatively simple mechanism. The difference between tools and machines lies primarily in the degree of automatism they have reached: the skilled tool-user becomes more accurate and more automatic, in short, more mechanical, as his originally voluntary motions settle down into reflexes, and on the other hand, even in the most completely automatic machine, there must intervene somewhere, at the beginning and the end of the process, first in the original design, and finally in the ability to overcome defects and to make repairs, the conscious participation of a human agent.
>
> Moreover, between the tool and the machine there stands another class of objects, the machine-tool: here, in the lathe or the drill, one has the accuracy of the finest machine coupled with the skilled attendance of the workman. When one adds to this mechanical complex an external source of power, the line of division becomes even more difficult to establish. In general, the machine emphasizes specialization of function, whereas the tool indicates flexibility: a planing machine performs only one operation, whereas a knife can be used to smooth wood, to carve it, to split it, or to pry open a lock, or to drive in a screw. The automatic machine, then, is a very specialized kind of adaptation; it involves the notion of an external source of power, a more or less complicated inter-relation of parts, and a limited kind of activity. From the beginning the machine was a sort of minor organism, designed to perform a single set of functions.[17]

Readers often have a superficial acquaintance with a concept without having much knowledge of its historical background. In the following paragraph Lynn Thorndike offers an *historical explanation* of the term *magic.*

[17] Lewis Mumford, *Technics and Civilization,* New York, Harcourt, Brace and Company, 1934, pp. 10-11.

> Some may think it strange that I associate magic so closely with the history of thought, but the word comes from the *Magi* or wise men of Persia or Babylon, to whose lore and practices the name was applied by the Greeks and Romans, or possibly we may trace its etymology a little farther back to the Sumerian or Turanian word *imga* or *unga,* meaning deep or profound. The exact meaning of the word, "magic," was a matter of much uncertainty even in classical and medieval times, as we shall see. There can be no doubt, however, that it was then applied not merely to an operative art, but also to a mass of ideas or doctrine, and that it represented a way of looking at the world. This side of magic has sometimes been lost sight of in hasty or assumed modern definitions which seem to regard magic as merely a collection of rites and feats. In the case of primitive men and savages it is possible that little thought accompanies their actions. But until these acts are based upon or related to some imaginative, purposive, and rational thinking, the doings of early man cannot be distinguished as either religious or scientific or magical. Beavers build dams, birds build nests, ants excavate, but they have no magic just as they have no science or religion. Magic implies a mental state and so may be viewed from the standpoint of the history of thought. In process of time, as the learned and educated lost faith in magic, it was degraded to the low practices and beliefs of the ignorant and vulgar. It was this use of the term that was taken up by anthropologists and by them applied to analogous doings and notions of primitive men and savages. But we may go too far in regarding magic as a purely social product of tribal society: magicians may be, in Sir James Frazer's words, "the only professional class" among the lowest savages, but note that they rank as a learned profession from the start. It will be chiefly through the writings of learned men that something of their later history and of the growth of interest in experimental science will be traced in this work. Let me add that in this investigation all arts of divination, including astrology, will be reckoned as magic; I have been quite unable to separate the two either in fact or logic. . . .[18]

Quite different from this question of historical relationships is the problem of defining something that is always with us. In defining the terms *weather* and *climate* Glenn T. Trewartha uses a combination of *analysis* and *comparison.*

> The condition of the atmosphere at any time or place, *i.e.*, the weather, is expressed by a combination of several elements, primarily (a) *temperature* and (b) *precipitation* and *humidity* but to a lesser degree

[18] Lynn Thorndike, *A History of Magic and Experimental Science,* Vol. I, New York, Columbia University Press, 1929, pp. 4-5.

by (c) *winds* and (d) *air pressure* as well. These four are called the *elements of weather and climate* because they are the ingredients out of which various weather and climatic types are compounded. The *weather* of any place is the sum total of its atmospheric conditions (temperature, pressure, winds, moisture, and precipitation) for a *short* period of time. It is the momentary state of the atmosphere. Thus we speak of the weather, not the climate, for today or of last week. *Climate*, on the other hand, is a composite or generalization of the variety of day-to-day weather conditions. It is not just "average weather," for the variations from the mean, or average, are as important as the mean itself.[19]

One of the most valuable methods of extending a definition is *illustration*. This method, used in the following example, is particularly appropriate in scientific writing because it directs the attention of the reader to the basis in fact and observation of the term to be defined.

Muscle is a tissue that generates motion. There are many sorts of motion and correspondingly there are different sorts of muscle. There is, for instance, the rapid voluntary movement, such as that of the wing muscle of the housefly with its three hundred full cycles per second, and there is the muscle of the clam which contracts once and may keep the shell closed for the rest of the week. Other muscles work by producing rhythmic involuntary movements or light changes in their "tone." The muscle of the pregnant uterus may be dormant for months, to enter into violent activity at the end of its term, and relapse into inactivity immediately after delivery. The slower autonomous movements are performed mostly by the so-called smooth muscles, which consist of spindle-shaped cells dispersed in our organs and blood vessels, while rapid voluntary movements are performed by the impressive mass of "cross-striated" muscles. . . .[20]

From the foregoing examples it is evident that many methods—among them analysis, enumeration, distinction, historical explanation, comparison, and illustration—may be used in developing an extended definition. The writer should not, however, select his method arbitrarily; his skill lies in foreseeing the ways in which a term is likely to be hazy or obscure to his readers and in offering the needed clarification. In scientific writing definitions are offered early in a

[19] By permission from *An Introduction to Weather and Climate*, 2nd ed., by Glenn T. Trewartha, p. 5. Copyright 1943. McGraw-Hill Book Company, Inc.

[20] A. Szent-Györgyi, *Chemistry of Muscular Contraction*, 2nd ed., New York, Academic Press, Inc., 1951, p. 8.

paper to explain the use of key terms and elsewhere as terms are introduced which may not be clear to the reader. Strictly technical writing requires fewer definitions than scientific writing in general since the reader may be assumed to have a comprehensive knowledge of the terminology of his specialty. However, even in technical writing it is sometimes necessary for the writer to define terms the meanings of which overlap or to explain which of variant systems of terminology or nomenclature he is following.

IV. DERIVATION AS AN AID IN MASTERING TERMINOLOGY

The words used in English as terms in the natural sciences come in the main from three sources: (1) they are inherited from much earlier times when the sciences were not divided into as many different disciplines as at present, (2) they are everyday English words used in a technical sense, (3) they are words borrowed from other languages or devised, usually through a combination of Greek or Latin roots, to fill new needs as they arise. Terms are very rarely entirely new coinages without recognizable antecedents. Edmund Andrews has noted as one of these rare coinages the word *gas*, which the seventeenth century Brussels chemist van Helmont devised on the model of the Greek *chaos* to designate the substance which fills the atmosphere, formerly supposed to be a void. After noting this exception, Andrews continues:

> Exceptions such as these serve merely to emphasize the fact that language flows as a continuous stream; nearly all words have fathers and forefathers going back into the mist of antiquity. "Derivation" is an irrigator's term. It originally described the various rivulets and rills he spread over his fields from a common source. Our purpose is to trace these rivulets as far as possible towards their sources. Here the dictionary fails us. Unfortunately, the quotations in the *Oxford Dictionary* go back only as far as 1300 A.D. For the scientist that is not enough. The English language may begin then, but the scientific language is that of thought. It goes back through French, Latin, Greek, and many other tongues to the dawn of learning, and it matters not a whit when and where these thoughts overlap linguistic boundaries. They are as continual as the flow of a river, perhaps dammed here and there at some language barrier, but always eventually overflowing as a waterfall.[21]

[21] Edmund Andrews, *A History of Scientific English*, New York, Richard R. Smith, 1947, p. 12.

As the preceding quotation suggests, the language of science has always been in a degree international. The symbols and many of the terms of science are internationally known and recognized. The elements from which many scientific terms are constructed have descended to us from ancient and medieval times when Latin was the international language of learning. Thus a student can learn a specialized terminology much more rapidly and accurately if he familiarizes himself with the Greek and Latin elements from which that terminology has been in part built up. This method is most applicable to the language of all science and, indeed, of all abstract thought. Though a study of the derivation of words is often thought of as an excursion into romance, it can be a real and practical help to the student of science.

A. Extensive Use of Greek and Latin

Comparatively few scientific terms have descended directly from ancient science; most are combined forms built up out of Greek and Latin elements. The word *pediatrician,* for instance, is made up of three such elements, *ped,* from the Greek word for child, *iatric* from the Greek word for healing, and the suffix *ian,* meaning *one who.* Combined they mean a physician who treats the diseases of children.[22] A limited number of prefixes, suffixes, and combining forms have been used many times over to form new terms. The *hema* or *hemo* (Greek *haima,* blood) appears at the beginning of thirty words in the *American College Dictionary;* in Stedman's *Medical Dictionary* fourteen columns are required to list the terms beginning with this form. The student, by learning a relatively small number of combining forms, can learn a scientific terminology rapidly; he need not learn the Latin and Greek languages themselves.

Frequent reference to a dictionary in the early stages of learning a science will give a student a knowledge of derivations on which he can build a strong scientific vocabulary. Moreover, most of the combining forms appear in common words from which they can be remembered. Guessing at derivations without using a dictionary,

[22] Charles Barrett Brown has observed that the literal translation of a word of Greek or Latin origin may take the place of a definition. *Gastralgia,* from the Greek *gaster* (stomach) plus *algos* (pain), means pain (class) in the stomach (differentia). Charles Barrett Brown, *The Contribution of Greek to English,* Nashville, Tenn., The Vanderbilt University Press, 1942, p. *ix.*

however, is hazardous since two distinct combining forms sometimes have the same English spelling. For example, people are often confused by the form *ped* (pedo) from the Greek *pais, paidos,* meaning child, as in *pediatrician* and *pedagogue,* and the form *ped* (pedi) from the Latin, *pes, pedis,* meaning foot, as in pedal, pedicle, and pediform.

In order to show the possibilities of rapid vocabulary building through a knowledge of classic roots, selected lists of Greek and Latin elements which have contributed to specialized terminology are given in Appendix A, p. 388. The items have been chosen and arranged to show how knowledge of the roots in a familiar word may be the key to the meaning of a difficult scientific term. These lists are intended only to point the way to further study. An extended list of Greek words which have contributed to English vocabulary is given with derivatives in Brown's *The Contribution of Greek to English.* Lists showing the derivation of medical terms are included in O. H. Perry Pepper's *Medical Etymology,* and examples showing the use of Greek and Latin forms in scientific terminology generally are given in John Newbold Hough's *Scientific Terminology.*

Occasionally an objection is raised to the large number of classical borrowings in science and an attempt is made to substitute simpler expressions, as *stain-haters* and *stain-lovers* for *chromophobes* and *chromophils* or *animals without backbones* for *invertebrates.* There remain, however, thousands of terms which cannot be translated without creating extremely clumsy compounds or circumlocutions. It should be remembered, also, that borrowing freely from Latin and Greek, and to a lesser extent from other languages, has been a habit of the English language for hundreds of years.

B. The Problem of Eponyms

An *eponym* is a term derived from the name of the person credited with the description, discovery, or invention which gave rise to the use of the term. Such terms record many chapters in the history of science; the genus of microorganisms known as *Rickettsia,* for instance, commemorates the work of the American scientist H. T. Ricketts (1871-1910), who established the transmission of Rocky Mountain spotted fever by the tick. Other eponyms familiar

to students in sciences are Fehling's solution in chemistry, Boyle's law in physics, Gresham's law in economics, the Binet-Simon test in psychology, the Pythagorean theorem in mathematics. Many eponyms, such as the Fahrenheit thermometer and the pasteurization of milk, have passed into everyday use.

In certain sciences, particularly medicine and anatomy, eponyms have become so numerous as to be confusing. Also, as Morris Fishbein has observed in *Medical Writing*, when a discovery is credited to several persons, national pride may lead to different names for the phenomenon in different countries. Because of the difficulties arising from the use of eponyms, various writers on scientific terminology have deplored their persistence. Others are reluctant to abandon eponyms because they perpetuate scientific history. Pepper gives an excellent and objective summary of the matter.

> Most eponyms perpetuate the name of the discoverer or the first describer of some structure or phenomenon, but few survive long for this reason alone. As a rule, an eponym remains in use only if no satisfactory term can be found to take its place. For example, no brief adequate term has ever been suggested to describe all that is conveyed by the ancient eponym "Hippocratic facies," with the sunken cheeks and pinched nose of the terminal moribund state. Nor have good substitutes come forward to push many of the anatomical eponyms into the discard. Fallopio (1523-1562) and Eustachio (1520-1574) still plague us with their respective tubes. The term "Broca's area" also is no help with our medical speech.
>
> Eponymic titles are given to diseases only for lack of something better. The name Bright's disease persisted longer than it should have, and the name Hodgkin's disease is still used because of our ignorance, in spite of the cumbersome substitutes suggested. Such eponyms persist and defy the advance of knowledge, but must always lose out in the end, when science learns enough to justify the coining of some appropriate term. Often an eponym is a clear indication of our ignorance, and constitutes a challenge to the investigator to rid our terminology of one more eponym. Any disease designated by an eponym is a good subject for research.[23]

The problems of eponymic terminology must be left to the specialist. But so long as eponyms exist—and some of them seem destined to

[23] O. H. Perry Pepper, *Medical Etymology*, Philadelphia, W. B. Saunders Company, 1949, pp. 11-12.

live a long time—they will lead the general reader into pleasant bypaths of scientific history.

V. THE MISUSE OF TECHNICAL TERMINOLOGY

Nothing which has been said in this chapter should be taken to justify the use of technical terminology where it is inappropriate. Good scientific style (see Chapter 8) does not permit the indiscriminate use of elaborate terminology. Nor do simple ideas gain scientific standing by being encumbered with erudite diction. Half a century ago Greenough and Kittredge in *Words and Their Ways in English Speech* stated a rule for guidance in choosing between "learned words and popular words": "The sole criterion of choice consists in the appropriateness of one's language to the subject or the occasion." [24] More recently, W. C. Allee, a successful writer for both general and technical readers, has summed up the case for simplicity and directness.

> Despite much practice to the contrary, any biological fact which concerns us can be accurately described and the conclusions from its study be clearly expressed in relatively simple and direct language.
>
> In research reports and scholarly discussions there is need for the conciseness and precision made possible by technical language. Science has no need, however, and is ill-served by any tendency to develop a cult of obscurity. Scientists must be free to attack the unknown as effectively as they can and in return for intellectual freedom they have an obligation, which rests heavily on those able to do so, to interpret research results in terms which can be understood by intelligent and interested people.[25]

Occasionally a writer or speaker who wishes to appear learned will not be content to use the terminology of one science but will borrow terms from several specialized fields and use them indiscriminately. Such a mixture may be impressive to the uninformed, but the informed reader is likely to conclude that the writer's confusion of mind is as great as his confusion of language. Such a misuse of scientific terminology is the mark of the pseudo-scientist rather than the scientist. The person of truly scientific mind respects words for what they represent.

[24] James B. Greenough and George L. Kittredge, *Words and Their Ways in English Speech*, New York, The Macmillan Company, 1901, p. 27.

[25] Reprinted by permission of the publisher, Abelard-Schuman, Inc., from *Cooperation Among Animals* by W. C. Allee, copyright 1938, 1951, pp. 17-18.

STUDY SUGGESTIONS

1. Discuss the variant meanings of the following words when used in different contexts: radical (mathematics and politics, for example), collaborator, correlation, co-ordinate, tonic (music, philology, medicine), equilibrium, insular, design, symbol, host, culture, potential.
2. Write a formal definition of each of the words in Exercise 1 as it is used as a term in a single field or discipline.
3. Write an operational definition of one of the following terms: specific gravity, square root, area, circumference, probable error, calorie.
4. Would it be possible to define *profession* operationally? *Anti-intellectualism?* If not, what type of definition would you choose to explain the sense in which you use and understand these words? As a class project, let each member of your class prepare a definition of one of these terms and compare the definitions to determine the extent of agreement.
5. Write an extended explanation of one of the following pairs of terms, using comparison and contrast as means of development: in vivo and in vitro, mistake and fallacy, stress and strain, meiosis and mitosis, function and dysfunction, ontogeny and phylogeny, colloquialism and provincialism, authoritative and authoritarian, mass and weight, evidence and proof.
6. Write extended explanations of the meanings of the following words, using derivation and historical background as means of development: empirical, paradox, cosmic, communication, panacea, cybernetics.
7. In *Harper's Magazine,* 209:34, July 1954, Ian Stevenson makes the statement: "I wish the word psychosomatic had never been invented. It has aroused new interest in an old subject, but at the same time—as so many words do—it has blocked the growth of wider concepts." In what sense may words be said to block the growth of wider concepts? Can you give other examples?
8. "It [mathematics] is a language, a tool, and a game—a method of describing things conveniently and efficiently, a shorthand adapted to playing the game of common sense or logic, as it is called in scientific circles. It is a human phenomenon, *not* an infallible proof of anything." Would you characterize the foregoing statements of Mario G. Salvadori in "Math's a Pleasure," *Harper's Magazine,* 209:90, August 1954, as definition or description? Comment on the choice of words (*language, tool, game*). What is the importance of the concluding statement?
9. Show the influence of the prefix or suffix in the following groups of words: traction, subtraction, contraction, distraction, retraction; en-

demic, epidemic, pandemic; synthetic, symphony, syndicate, syntax, synonym; scientist, artist, analyst, deist.

10. E. G. Conklin in *Heredity and Environment* objects to the dictionary definition of *heredity* as "the transmission of qualities or characteristics, mental or physical, from parents to offspring" on the ground that the qualities or characteristics as such are not transmitted from one generation to the next. Can you formulate a more satisfactory definition of *heredity?*
11. Stuart Chase in *Power of Words*, p. 276, refers to a saying at Antioch College, "Education is the only commodity that the customer tries to get as little of as he can for his money." What relationship does this statement have to the formal definition?

CHAPTER 4 COLLECTING DATA

I. Locating source material
   A. Bibliographic aids
   B. The questionnaire and the interview
II. Evaluating sources of data
   A. Primary and secondary sources
   B. The consideration of authority
   C. The relevance of date
III. Recording data
   A. The card file system
      1. Bibliography cards
      2. Note cards
   B. Good procedure in note-taking
IV. A list of reference works

> *Wherever there is the slightest possibility for the human mind to* know, *there is a legitimate problem of science.* KARL PEARSON, The Grammar of Science.

I. LOCATING SOURCE MATERIAL

The data in original scientific papers and reports are derived from varied sources. Archaeologists dig deep into the earth for knowledge of the past, as did those who have been seeking the ancient tombs of the Pharaohs. Naturalists observe the minutiae of plant and animal life, as Darwin did during the journey recounted in *The Voyage of the Beagle*. Oceanographers enter the seas, as William Beebe did in photographing life on the ocean floor. The astronomer searches the heavens; the chemist or physicist experiments in his laboratory; the physician studies his clinical notes.

Such scientific findings are unavailable for general study until they are housed in museums or recorded in print and deposited in libraries. There these records in turn become sources of material for further research. Indeed, the existence and value of many library

materials is wholly due to faithful recording of work done in the field and in the laboratory. Here, as Francis Bacon put it, "Books must follow sciences, and not sciences books."

The methods used in field and laboratory investigation must be learned through the individual sciences; these methods are necessarily excluded from this chapter, which deals primarily with library research. The questionnaire and interview—exceptions to this rule—come within the scope of the chapter insofar as they may be regarded as general, nontechnical methods of investigation.

A. Bibliographic Aids

In library research difficulties may arise from an overabundance of material related to the subject. The question "Can I find enough material?" is often beside the point. On the single subject of aureomycin, for example, the Lederle laboratories have listed a bibliography of 1,915 papers published between November 1948 and November 1950. The *World List of Scientific Periodicals*[1] refers in its Preface to a coverage of 50,000 publications. In this vast maze of published matter, the writer must locate the sources which deal with his problem and select those which meet his needs.

The usefulness of the card catalog, encyclopedias, and other general reference works is recognized by most students who undertake research. Such general guides often lead, however, to secondary sources of limited value to the specialist. This chapter, therefore, will emphasize the use of the more specialized reference materials.

It is good practice in searching for material on a scientific subject to begin with recently published papers. Beginning with current publications and working back through earlier issues will often save time which might otherwise be wasted on outdated observations and involved discussions of theories later revised or discarded. An especially helpful type of paper is what is known in science as a "review." (See Chapter 10.) Some scientific publications, such as *Chemical Reviews*, are devoted to papers which summarize and interpret the reports which have previously appeared on a research problem. It is a good plan, also, to begin with recent issues in using indexes and abstracts.

[1] *World List of Scientific Periodicals 1900-1950*, 3rd ed., New York, Academic Press, Inc., 1952.

The *index* may be defined as a detailed alphabetical key to names, places, and topics in a book, an encyclopedia, periodicals, or other printed matter. The index may appear at the end of a book or, like periodical indexes, may be issued in separate volumes appearing at intervals. It may be general in nature like *The Readers' Guide to Periodical Literature* or highly specialized like the *Index Medicus.* Some publications list separately author, title, and subject indexes; in such cases all three indexes must be checked. Wherever the index appears, its alphabetical arrangement permits quick reference, usually to a wide range of material.

An *abstract* is by definition a summary or condensation—usually short—of a statement, document, article, or lecture. As used in science, it serves as both a reference to an article and an indication of its content. (See Chapter 13.) The use of abstracts involves more steps than the use of an ordinary index. You first look up the author or topic in an index which will give the reference to an abstract of the original article. You then consult the abstract, which will contain a reference to the journal in which the original article appeared, in the event you should want to read it. Abstracts do not serve as satisfactory substitutes for the original articles and should never be treated and quoted from as original sources. If the original is not available locally, the abstract makes it possible to decide whether to look for the article elsewhere. If an original is unobtainable, it may be permissible in a student bibliography to list the abstract if its nature is clearly indicated.

Abstracting services of great importance to students of science are *Biological Abstracts*, published under the sponsorship of the Union of American Biological Societies, and *Chemical Abstracts*, published by the American Chemical Society. In addition to the annual index, *Chemical Abstracts* has *Decennial Indexes*, of which the fourth appeared in 1946. One of the most ambitious abstracting services ever undertaken is *Excerpta Medica*, begun in 1947 and designed to present abstracts "of every article in the fields of clinical and experimental medicine from every available medical journal in the world." Although these abstracts are published in Amsterdam and cover journals in many languages, they appear in English.

A *bibliography* is a complete or selective list of works concerning an individual author or subject. In addition to the bibliographies

which accompany scientific and scholarly books and articles, many bibliographies are published separately. Annotated bibliographies, which include short descriptions of the individual items, are particularly useful. Available bibliographies on a subject may often be located through "bibliographies of bibliographies," such as the *Bibliographic Index* and Besterman's *World Bibliography of Bibliographies.*

Section IV of this chapter lists dictionaries, encyclopedias, indexes, abstracts, bibliographies, and other reference works. Nevertheless, though bibliographies, indexes, and abstracts are indispensable aids in scientific research, they cannot be depended upon to list all the references on a subject. Cross references, footnotes, and chance allusions will sometimes offer the only clues to some sources of information.

The question often arises as to how extensive a coverage of sources is necessary. For most student papers a selective coverage is sufficient. On advanced levels of research the coverage approaches the scholarly ideal of completeness. (The question of coverage will be treated in more detail in Chapter 10, The Research Paper.)

B. The Questionnaire [2] and the Interview

The *questionnaire* has been defined as "a set of questions to be answered by the informant without the personal aid of an investigator or enumerator." [3] The successful use of the questionnaire depends largely upon the skill with which it is planned, framed, and distributed. As a research tool, the questionnaire requires judicious control even in the hands of the expert. It is hoped, however, that the suggestions offered here will serve to enable the student to discriminate among claims and findings based on the use of the questionnaire.

Once the purpose of the questionnaire is defined and the nature of the information desired is clearly in mind, clear and specific questions should be framed to elicit the information from the informants. For example, it is better to say, "From what institution

[2] In addition to its use as a tool in social science research, the questionnaire is, of course, commonly employed commercially in market research, opinion, and poll surveys.

[3] Wilson Gee, *Social Science Research Methods*, New York, Appleton-Century-Crofts, Inc., 1950, p. 314.

did you receive your undergraduate degree?" than "Where did you attend college?" Results are easier to tabulate if the questions are "closed"—that is, questions to which the possible answers are limited to "Yes" or "No" or to a few choices such as "Poor," "Fair," "Good," "Excellent." However, "open" questions permitting greater freedom of response must be used if the range of replies cannot be predicted or if the purpose is to encourage the free expression of ideas. Leading questions—questions so framed as to suggest the answer desired—should be avoided. Replies to a questionnaire will be encouraged if it is accompanied by a letter explaining its purpose and by directions telling how to fill it out and return it. (An example of a questionnaire used for a specific purpose appears in Appendix A, p. 397.)

In spite of its usefulness, the questionnaire has incurred criticism because it has at times been indiscriminately used and the results injudiciously interpreted. (See Chapter 6.) Certain criteria are pertinent in evaluating a questionnaire and its findings.

1. Was the questionnaire directed to a specific purpose?
2. Was the information requested restricted to facts or to the expression of opinions which would not be affected by emotional bias?
3. Did the number of replies to the questionnaire represent an adequate sampling of the group?
4. Could the responses obtained be considered representative of the group as a whole?

Useful as the questionnaire is, it cannot replace the personal interview. Sometimes a single individual is in possession of a large part of the information desired and will express himself more freely and more willingly in an interview than in a questionnaire. Again, the interview may uncover unexpected or unanticipated information. Adequate preparation for the interview and an accurate record are as important as the conduct of the interview itself. A tactful letter requesting an appointment should explain the purpose for which the information is needed and the use to which it will be put. This letter should also indicate the probable length of time required for the interview and the scope and nature of the inquiries to be made. In the interest of accuracy the record should be made as soon after the interview as possible.

The following suggestions originally offered in a course in Industrial Publishing of the New York Business Publishers Association may serve as a guide for the conduct of the interview.

1. Make a definite appointment with the man to be interviewed, and keep it to the minute.
2. Learn as much as possible about him before you go to the interview. . . .
3. Know the subject of the interview. The best interviewer is one with whom the interviewed can talk on something like equal terms and not have to explain every little thing in ABC language.
4. Do not expect the interviewed to volunteer information or to take the lead in conducting the interview; that is your job.
5. Frame in advance some pertinent questions that get at the heart of the subject.
6. Do only as much talking as is necessary to keep the person interviewed talking.
7. Observe the courtesies of your position. Don't argue, don't contradict, don't insist. Discuss the points that require some comeback in order to bring out their meaning, or to bring up the other side of the question, or to keep the interview moving.
8. Keep some . . . questions up your sleeve with which to bring the interview back to its subject matter, if the interviewed becomes discursive.
9. If the information quoted is of an important character, or involves many statistical references, figures, mathematical formulas, or other exact statements requiring careful checking, it is generally best to submit a written record of the interview for approval before printing it.
10. Do not overstay your time. Leave while the going is good.[4]

II. EVALUATING SOURCES OF DATA

Broadly speaking, everything on earth is a source of knowledge about some phase of natural processes or human activity. A schoolboy's letter may be just as valid a source for the purpose of studying child psychology as a letter of Woodrow Wilson's is for the purpose of studying the history of World War I. Some of our knowledge of Greek civilization is derived from the ornamentation of Greek vases; we learn of medieval musical instruments from their depiction in art works of the time. The evaluation of sources involves distinguish-

[4] Frank Kerekes and Robley Winfrey, *Report Preparation,* 2nd ed., Ames, Iowa State College Press, 1951, p. 58.

ing between primary and secondary sources, weighing of authority as to competence and bias, and considering the significance of the date.

A. Primary and Secondary Sources

It is customary to classify sources as *primary* and *secondary*. The primary, or first, source of knowledge is, in one sense, the original experiment, the insect preserved in amber, the inscription on an ancient tomb, that is, the source which precedes the first written record.

The distinction between primary and secondary sources is usually, however, applied to written or printed sources. While in scientific work the final referent is always experiment or observation, no scientist can possibly repeat all the experiments of others. In scientific literature the scientist's original reports of his experiments are considered primary sources; reviews and books of others who analyze and interpret these original reports are regarded as secondary sources. For example, in a study of the work of Antoine Lavoisier, which profoundly altered the science of chemistry, Lavoisier's notebooks, reports, and treatises would be primary sources. All the biographical, historical, and scientific works which have been written about Lavoisier since he was guillotined at the time of the French Revolution would be secondary sources.

The writer of a research paper will use primary and secondary sources for different purposes. Though there is no substitute for first-hand knowledge, an authoritative secondary source will give perspective and permit the intelligent use of primary sources. The secondary source which is based on other secondary sources or which stresses sensational details should be treated with great caution. Wherever possible the reliability of a secondary source should be checked against the primary source. Encyclopedias are, of course, always secondary sources and are subject to misuse. While an authoritative encyclopedia affords a balanced account of a broad and complex subject and may offer useful references, not even the beginning student should limit himself to encyclopedias or become dependent upon them. A paper can be no better than its sources, and it is expected that a research paper (see Chapter 10) will include repre-

sentative primary sources and exclude those secondary materials which are remote from the original source of knowledge.

B. The Consideration of Authority

Whether a source is primary or secondary, the degree of authority it represents should be considered. Two factors are generally held to affect the authority of a source: competence and bias. In a scientific or technical field *competence* is not ordinarily difficult to establish. Workers who have been adequately trained in a specialized field are supposedly qualified to report their own experimental results. Each field has its recognized leaders or experts. When a source appears doubtful, the professional affiliations of the author and the reputation of the agency which issued the publication are guides to its reliability.

Bias, or a writer's tendency to observe, select, and interpret data from a distorted or limited point of view, may be difficult to detect. Charles V. Langlois and Charles Seignobos have suggested questions which test the good faith and accuracy of writers.[5] Mary E. Richmond has summed up these questions as they apply in social work, but they are applicable to writing in all sciences.

> *Good Faith.* Were there any practical advantages to be gained by the witness who made the statement in its present form? Had he an interest in deceiving? What interest did he think he had? (We must look for the answer in *his* tastes and ideals, not in our own.) If there was no individual interest to serve, was there a collective interest, such as that of a family, a religious denomination, a political party? . . . Was some rule or custom, some sympathy or antipathy, dominating him? Was personal or collective vanity involved? Did his ideas of etiquette, of what politeness demanded, run counter to making a perfectly truthful statement? . . . Or again, has he been betrayed into telling a good story, because it made an appeal to the artistic sense latent somewhere in all of us?
>
> *Accuracy.* Was the statement an answer to a question or a series of questions? (It is necessary to apply a special criticism to every statement obtained by interrogation.) What was the question put, and what are the preoccupations to which it may have given rise in the mind of the person interrogated? Was the observer well situated for

[5] Charles V. Langlois and Charles Seignobos, *Introduction to the Study of History*, translated by G. Berry, London, Duckworth and Company, 1898, pp. 164-77.

observing? Was he possessed of the special experience or general intelligence necessary for understanding the facts? How long before he recorded what he observed? Or did he record it, like some newspaper accounts of meetings, before it happened? Finally, was the fact stated of such a nature that it could not have been learned by observation alone? [6]

The forms of bias detected by these questions arise chiefly from two causes, direct self-interest and indirect self-interest. *Direct self-interest* may be suspected wherever material or financial gain is involved. For this reason the amount and character of advertising are limited in scientific publications. In general, trade journals or publications supported by commercial agencies, though they may contain useful material, do not have the same scientific standing as publications supported by scientific organizations, educational institutions, or endowments. However, some commercially sponsored publications have achieved high standing.

On a much lower level are pseudo research agencies which may have high-sounding titles but are actually engaged only in "proving" what the promoters wish proved. The antecedents of suspect agencies should, as Richard D. Altick has suggested, be subjected to intensive inquiry.

> . . . in recent times it has been increasingly the custom for advertisers to borrow the prestige of science and medicine to enhance the reputation of their products. The American people have come to feel for the laboratory scientist and the physician an awe once reserved for bishops and statesmen. The alleged approval of such men thus carries great weight when it is a question of selling something, or (which is the same thing) inducing someone to believe something. Phrases such as "leading medical authorities say . . ." or "independent laboratory tests show . . ." are designed simply to transfer the prestige of science, which presumably is incapable of either error or corruption, to a toothpaste or a cereal. Seldom if ever are the precise "medical authorities" or "independent laboratories" named. But the mere phrases have vast weight with the uncritical. Similarly too the honorific "Dr." or "professor" implies that the person quoted speaks with all the authority of which learned men are capable—when as a matter of fact "doctorates" can be bought from mail-order colleges. Whenever, therefore, an attempt is made to convince by appeal to the prestige that surrounds the learned, the reader should demand full

[6] Mary E. Richmond, *Social Diagnosis*, New York, Russell Sage Foundation, 1917, p. 64.

> credentials. Just *what* medical authorities say this? Can they be trusted? *What* independent laboratories made the test—and what, actually, did the tests reveal? Who is this man that speaks as a qualified educator or psychologist or economist? Regardless of the fact that he is called "doctor," does he know what he is talking about? [7]

Indirect self-interest may be due to the writer's identification with a group, such as a nation or race, a religious denomination, or a political party. Even the impulse to tell a good story, which in science may manifest itself as the desire to make a sensational discovery, stems from what Miss Richmond calls "collective self-esteem." Bias due to indirect self-interest occurs in both the natural and the social sciences. International in scope as science has always been, national predilections have at times hampered scientific progress. The French physicians of William Harvey's time were, for example, slow to appreciate the Englishman's discovery of the circulation of the blood. A recent instance of extreme bias which has attracted wide attention is the suppression in the Soviet Union of accepted theories of genetics and the promotion in their place of the theory of T. D. Lysenko, which, though it "goes along with the philosophy required by Marx and Lenin," "brushes aside all of the careful and tested results of genetic work of the past forty years." [8]

The influence of bias is marked in the social sciences where issues of regional, social, or economic interest are involved. Differences of opinion expressed on the United States Supreme Court's decision on segregation in the public schools followed largely geographical lines. An individual's views on taxation, farm policy, the tariff, social security, universal military service, and other public questions all tend to be influenced by his political and organizational affiliations, his age, his geographical environment, and his economic status. The reader in the social sciences must frequently raise the question, "Is this writer the spokesman for any pressure group?"

A source is not necessarily to be discarded because it is biased. In historical research it may be necessary to weigh the accounts of several biased witnesses in an endeavor to get at the truth of the matter. (See Appendix A, p. 399.) Or, if the writer is making a study

[7] Richard D. Altick, *Preface to Critical Reading*, New York, Henry Holt and Company, 1951, pp. 145-46.

[8] Harold H. Plough, "Bourgeois Genetics and Party-line Darwinism," *The American Scholar*, 18:291-303, Summer 1949.

of prejudice or individual differences, the bias of a source may add to its value. However, bias should always be taken into account and allowance made for it.

Everyone, it should be noted, has some degree of *honest bias* in the sense of preconceived ideas and natural bent of mind. Some political scientists are known to have a conservative, others a liberal outlook. The psychologist's point of view differs from the geneticist's, the anatomist's from the physiologist's, the engineer's from the physicist's, the sociologist's from the archaeologist's. In both the natural and social sciences there are schools of thought whose adherents differ in approach or terminology, sometimes even in basic assumptions. This sort of bias should be carefully distinguished from the dishonest or unreasoned bias which leads a writer to misrepresent or distort facts.

C. The Relevance of Date

A final point to be considered in evaluating any source is its date. In checking the literature you should make sure that you have obtained the most recent material on your subject. In a rapidly changing field, out-of-date material may be valueless. In every branch of science, however, certain classics, such as Darwin's *Origin of Species*, will always have historic and even intrinsic interest; and a secondary source does not supersede the primary source on which it is based simply because the secondary source is of later date. Like other factors used in evaluating a source, the date should be considered in relation to the purpose for which the source is to be used. In any event, the date should never be disregarded.

III. RECORDING DATA

After a source has been located and its value determined, the task remains of taking notes from it for eventual use in writing. The longer and more ambitious a research project is, the more important an efficient system of taking notes becomes. It is an advantage in undergraduate courses to become acquainted with and employ a system which will prove adequate for even the most advanced work. The card file system, which involves the keeping of notes on cards which can be conveniently arranged and filed, is generally used for research.

A. The Card File System

In following the card file system as recommended here, you keep for each research project a file of cards, the most popular sizes being 3 x 5, and 4 x 6, and for notes perhaps 5 x 8. For each book, article, or other source used, you prepare a *bibliography card,* giving all the information which will be needed in listing the bibliography at the end of the paper and in identifying the source when it is first cited in the footnotes. On other cards, known as *note cards,* you record the notes to be used in writing the paper; from these note cards you will also get the page references for the footnotes. The use of two types of cards saves time since it is not necessary to repeat the bibliographical information on the numerous note cards and since all the bibliography cards can be kept together for use in preparing and, as necessary, revising the bibliography.

The wide use of the card file system has made its general outlines familiar to most students. Its usefulness in library research has been proved many times. The cards have several advantages over a notebook: they are easier to handle, more convenient to arrange and rearrange, and better adapted to the insertion of new material at appropriate points. Although this system is not intended to supplant data sheets or other forms for keeping laboratory records, variations of it are frequently used for keeping records of experimental research.

1. Bibliography Cards

It is essential that the *bibliography card* contain all the information needed for the bibliography. Time will be saved in copying the information from the cards if the order, punctuation, and other formal details of the entry appear exactly as they will in the final bibliography. For this reason, those who plan to document their papers according to one of the special systems of documentation, such as those used in certain biology and chemistry journals (see Chapter 14), should use the same form for their bibliography cards, as illustrated in the examples in this section.

The essential items on a bibliography card for a *book* are the author, title, place of publication, date of publication, publisher, edition if not the first, number of volumes if more than one, and number of pages. The bibliography card may also include the

BIBLIOGRAPHY CARD—BOOK—HUMANITIES DOCUMENTATION

574.97 Smallwood, William Martin, in collaboration with Mabel Sarah Coon Smallwood, <u>Natural History and the American Mind</u>. New York, Columbia University Press, 1941. 445 pp.

(development of natural history in U. S. from colonial times to latter part of 19th century. illus.)

Check List

1. Author
2. Title
3. Place of publication
4. Publisher
5. Date
6. Number of pages
7. Description (if desired)
8. Call number (if desired)
9. Edition (if needed)
10. Number of volumes (if more than one)

BIBLIOGRAPHY CARD—PERIODICAL ARTICLE—HUMANITIES DOCUMENTATION

Cournos, John, "God, Existentialism and the Novel," <u>The American Scholar</u>, 18:116-24, Winter 1948-49.

Check List

1. Author
2. Title of article
3. Name of periodical
4. Volume (and issue number if needed)
5. Pages
6. Date

BIBLIOGRAPHY CARD—BOOK—DOCUMENTATION REPRESENTATIVE OF CHEMICAL JOURNALS

B 610 R	Glasser, Otto, "Wilhelm Conrad Rontgen," Chap. 14, pp. 293-307, Springfield, Illinois, Charles C. Thomas, 1934. (a discussion of observations made in 1896 on the effects of roentgen rays on the human skin and on early experiments with X-ray therapy.)

Check List

1. Author
2. Title
3. Chapter and pages
4. Place of publication
5. Publisher
6. Date

BIBLIOGRAPHY CARD—PERIODICAL ARTICLE—DOCUMENTATION REPRESENTATIVE OF CHEMICAL JOURNALS

Grosse, A. V., Kirshenbaum, A. D., and Hindin, S. G., <u>Science</u>, <u>105</u>, 101 (1947)

Check List

1. Author
2. Name of journal
3. Volume number
4. Page reference
5. Date

BIBLIOGRAPHY CARD—BOOK—DOCUMENTATION REPRESENTATIVE OF BIOLOGY JOURNALS

> LINEBACK, P. 1933 Anatomy of the Rhesus Monkey. Ed. by G. C. Hartman and W. L. Straus, Jr. Williams and Wilkins Co., Baltimore. Chap. XII, 248-65.

Check List

1. Author
2. Date
3. Title
4. Editors
5. Publisher
6. Place of publication
7. Chapter and pages

BIBLIOGRAPHY CARD—PERIODICAL ARTICLE—DOCUMENTATION REPRESENTATIVE OF BIOLOGY JOURNALS

> McFARLANE, W. D., and H. I. MILNE 1934 Iron and copper metabolism in the developing chick embryo. J. Biol. Chem. <u>107</u>:309-19.

Check List

1. Author
2. Date
3. Title of article
4. Name of journal
5. Volume number
6. Pages

number of pages in the introduction and, if desired, the library card number and brief descriptive notes about the book.

The essential items on a bibliography card for a *periodical article* are the author, title of article, name of journal, volume number, number of issue if needed, page numbers, and date. Bound journals are ordinarily referred to by the volume number; if each issue in the volume begins with page one, or if the issue number is needed for any other reason, the reference should include the number of the issue, placed in parentheses between the volume and the page number, thus, 19(3):16-23.

2. Note Cards

The essential items for a *note card* are the topic of the note, a designation of the source (abbreviated if desired), the page reference, and the note itself in either summary or quoted form. A topic should always be devised to head the note card because a topical heading will be an aid in classifying and arranging the notes. A specific topic will be much more useful for this purpose than a general one. For example, such a heading as "Life of Pasteur" will be of little value since many other notes will be concerned with the same topic. A more specific heading, such as "Pasteur's methods of work," "Spontaneous generation controversy," or "Pasteur's devotion to the laboratory," would identify the note with greater accuracy.

The designation of the source and the page numbers should be carefully recorded on the note card because these items will be needed for use in preparing the footnotes, and correct identification is imperative. Some authorities suggest assigning a number to each source and using these key numbers on the note cards, but designating the source on the note card by an abbreviated form of the title has the advantage of being self-explanatory and of obviating the necessity for setting up and using a numerical key.

The purpose of the study determines both the content and the character of the note. Notes which are useful for one purpose may have no value whatsoever for another. One note-taker may select from a page only an anecdote which illustrates a point he has in mind. A cogent summary of a passage may meet the need of another. An author's main topic or central theme, historical facts, or statistical data may be pertinent to still a different purpose. Specific points

such as dates and names of persons should be recorded with particular care. Such details easily escape the memory, and if they are not available when the paper is written, it is likely to take on the washed-out, colorless style often characteristic of secondary sources.

In recording notes you must choose between paraphrase and direct quotation from the source. Quotation may be preferable when the original wording is striking or epigrammatic, when the statement is controversial and may be questioned, or when it is desirable to illustrate the style of a writer or period. It is not justifiable to copy long passages through inability or disinclination to make discriminating choices. In transcribing quoted matter, you should take the greatest care to copy accurately the words, capitalization, punctuation, and even any errors which may appear in the original, and to indicate by the use of quotation marks exactly where the quoted passage begins and ends. If the quoted passage begins on one page of the original and ends on another, it is desirable on the note card to indicate the page division by a bar, thus, ". . . the variety appears to be / the same as . . ." Then, if only part of the quotation is used in the finished paper, the information needed for a correct page reference in the footnotes will be available. No omissions may

NOTE CARD—SUMMARY FORM

```
              Microscope--history of
Smallwood, Nat. Hist.
and Am. Mind.

         Although the microscope was well under-
         stood by the beginning of the 19th
p. 195   century, its use required so many
         adjustments in thought and language
         that it did not come into general use
         in laboratories before 1880.
```

Check List

1. Topic
2. Source
3. Page reference
4. Note

NOTE CARD—QUOTATION

The empirical nature of Babylonian mathematics

E. T. Bell,
Dev. of Math.

"A third distinction which sharply separates the Archimedean mensuration of the circle from the Babylonian is exactly the distinction between scientific and prescientific thinking. A mind which rests content with a collection
p. 45 of facts is no scientific mind. The formulas in a mathematical handbook are no more mathematics than are the words in a dictionary a literary masterpiece. Until some unifying principle is conceived by which an amorphous mass of details can be given structure, neither science nor mathematics has begun."

Check List

1. Topic
2. Source
3. Page reference
4. Note

NOTE CARD—PART QUOTATION

Philosophy in current fiction

Cournos,
"God, Existentialism
and the Novel."

Comments that current fiction deals
p. 116 with "life and death, with God and moral values, above all with rèsponsibility."

Check List

1. Topic
2. Source
3. Page reference
4. Note

be made which alter the intent of the original statement. Permissible omissions may be indicated by the use of three dots at the beginning or within a sentence or four dots at the end of a sentence. It is equally unpardonable to make use of an author's words without employing quotation marks and to ascribe quotations to him inaccurately; you should remember that you will be dependent on your notes for the information needed for the correct handling of quotations in your paper.

B. Good Procedure in Note-taking

Sometimes you may find it impossible to take full notes on a book at the time of the first reading, or you may prefer not to dull the pleasure of reading by full note-taking. Under these circumstances you may for the time being choose to jot down only the page number and a brief note indicating the relation of the material to your purpose. If there are few interruptions for note-taking, you will see the material in better perspective and will be better able to judge what is relevant to your purpose.

Before letting the reference leave your hands permanently, you should make sure that the bibliography and note cards include every item of information which you will need for use in your research project. Almost everyone who has done research has had the experience of wishing to make use of a reference or passage which had come to his attention earlier but which had been lost to him through his failure to make proper notes at the time the material was at hand. Careful note-taking may at first seem laborious. However, it soon gains the ease of habit and any additional effort will be compensated for by the comparative facility with which a paper may then be written.

Much of this chapter has been devoted to the mechanical side of gathering material for research papers. However, the accumulation of information which bears on a problem is never a mechanical task. The purpose of the research and the questions to which answers are sought must guide each stage of the work.

IV. A LIST OF REFERENCE WORKS

GENERAL

The Census Volumes, United States Department of Commerce, Bureau of the Census

Chambers's Encyclopaedia, new edition

Encyclopedia Americana

Encyclopaedia Britannica

Foreign Commerce Yearbook, United States Department of Commerce

The Municipal Year Book

Official Gazette of the U. S. Patent Office

The Statesman's Year-book

The World Almanac and Book of Facts

BIBLIOGRAPHIES, CATALOGS, AND GUIDES TO SCIENTIFIC LITERATURE

Basic List of Current Municipal Documents

Besterman, Theodore, *A World Bibliography of Bibliographies*, 2nd edition

Bibliography of Scientific and Industrial Reports, United States Department of Commerce

Chamberlin, W. J., *Entomological Nomenclature and Literature*

Handbook of Medical Library Practice

Hawkins, Reginald Robert, *Scientific, Medical and Technical Books Published in the United States of America, 1930-1944*

Mellon, M. G., *Chemical Publications, Their Nature and Use*

Moor, Carol Carter and Waldo Chamberlin, *How to Use United Nations Documents*

Pearl, Richard M., *Guide to Geologic Literature*

Postell, W. D., *An Introduction to Medical Bibliography*

Smith, Roger C., *Guide to the Literature of the Zoological Sciences*, revised edition

Soule, Byron A., *Library Guide for the Chemist*

The United States Catalog, 1928; *Cumulative Book Index*, supplement to *The United States Catalog*

United States Government Monthly Publications Catalog

The United States Quarterly Book List

Winchell, Constance M., *Guide to Reference Books*
World List of Scientific Periodicals, 3rd edition

INDEXES

Agricultural Index
Bibliographic Index, A Cumulative Bibliography of Bibliographies
Book Review Digest
Bulletin of the Public Affairs Information Service
Current List of Medical Literature
Education Index
Engineering Index
Index Medicus; since 1926, *Quarterly Cumulative Index Medicus*
Index to Dental Literature
Industrial Arts Index
International Index to Periodicals
New York Times Index
Psychological Index
Readers' Guide to Periodical Literature
Technical Book Review Index
Zoological Record

ABSTRACTING JOURNALS

Biological Abstracts
British Abstracts
Chemical Abstracts
Excerpta Medica
Geophysical Abstracts
Mineralogical Abstracts
Psychological Abstracts
Science Abstracts

BIOGRAPHICAL REFERENCES

Cattell, Jaques, editor, *American Men of Science*, 8th edition
Current Biography
Dictionary of American Biography
Dictionary of National Biography
Who's Who
Who's Who in America

STUDY SUGGESTIONS

1. Choose a subject or individual, preferably in your own field or in one with which you have some familiarity, about which there has been considerable controversy, such as TVA, "survival of the fittest," the age of the universe, the "recapitulation" theory in human embryology, Mary Todd Lincoln, the origin of language. Look up this topic in several standard reference works and compare the treatments of the subject, noting particularly (a) the space devoted to it, (b) the agreement or lack of agreement as to coverage of specific points, (c) any differences of opinion. How do you account for any discrepancies you find?
2. Select a topic which you have some reason to investigate, or one suggested by the instructor, and locate six references on it, using as many different means as possible (i.e., indexes, abstracts, bibliographies, cross references). Prepare a bibliography card for each reference. Prepare a bibliography from the cards, using a format usual in the humanities. Convert this bibliography to one of the formats representative of scientific journals. (See Chapter 14.)
3. Consider a list or group of references from a textbook you are using. How many of the references would you classify as primary, how many as secondary sources?
4. Discuss the effects of translation, abridgment, censorship on the validity of a source, citing any examples which may have come within your experience.
5. Choose at random a topic in your field and look it up in sources of about 1910, 1925, and the present. Compare the treatments of the topic.
6. Discuss the relative values and uses of primary and secondary sources and show why neither can be ignored in undertaking the study of a subject.
7. Frame a short questionnaire with the purpose of inquiring into student attendance at convocations and preferences as to types of programs. Compare your questionnaire with those of other members of your class. Do the questionnaires have any of the weaknesses mentioned in section I-B of this chapter?
8. In preparation for a reference or research paper which you expect to write later, prepare three note cards: one in summary form, one a paraphrase, and one a quotation.

CHAPTER 5 ANALYSIS: METHODS AND APPLICATIONS

I. Analysis defined
II. Methods of analysis
  A. Partition
  B. Classification
    1. Principles of classification
    2. Patterns of classification
III. Presentation of analysis
  A. Tabular form
  B. Outline form
IV. Function of analysis in planning the paper
  A. Analytical treatment of subject matter
  B. Formal and informal analysis
V. Applications of analysis
  A. Analysis and prediction
  B. Analysis and practical problems

> *It is in everything else as it is in colors; bad eyes can distinguish between black and white; better eyes, and eyes much exercised, can distinguish every nicer gradation.* VOLTAIRE, A Philosophical Dictionary.

I. ANALYSIS DEFINED

The term *analysis*, deriving from a Greek verb meaning to loosen up, denotes a division into component parts or elements. Its graphic synonym *breakdown* is familiar in such expressions as a "breakdown of costs" or the "breakdown of a bill." In chemistry the term analysis refers to the breaking down of a compound into its elements or of a substance into its ingredients as to kind (qualitative analysis) or as to amount (quantitative analysis). Used less literally, as in speaking of the analysis of a situation, or of a person as having an analytical mind, the concept of analysis has the significance of mentally taking apart an abstract whole in order to understand its make-up.

Analysis is often closely associated with interpretation. However, *analysis* refers to the arrangement of matter or data, *interpretation* to the conclusions based on the matter or data presented. This distinction is strictly observed in scientific papers where the "Results," often analytically presented, and the "Discussion" of results are treated in separate sections.

Analysis, a process of division, is often contrasted with synthesis, a process of putting together or combining elements. The complementary relationship between analysis and synthesis may be shown by again referring to the science of chemistry. Historically an analytical science in which compounds are reduced to their elements, chemistry has more recently developed as a science of synthesis in which elements are combined into new compounds such as dyes, perfumes, plastics, and rubber.

> The French chemist Lavoisier in 1793 defined chemistry as "the science of analysis." The German chemist Gerhardt in 1844 said: "I have demonstrated that the chemist works in opposition to living nature, that he burns, destroys, analyzes, that the vital force alone operates by synthesis, that it reconstructs the edifice torn down by the chemical forces." . . .
>
> It was, I think, the French chemist Berthelot who first clearly perceived the double aspect of chemistry, for he defined it as "the science of analysis *and synthesis*," of taking apart and of putting together. . . . Since Berthelot's time, that is, within the last fifty years, chemistry has won its chief triumphs in the field of synthesis.[1]

The process of synthesis, like that of analysis, may be used in working with ideas as well as with things. The student of social situations may first analyze these situations into their elements and then mentally rearrange and recombine the elements in his search for new understanding. Thus analysis and synthesis are often used together in arriving at interpretations.

II. METHODS OF ANALYSIS

All analyses have in common the element of *division*. In achieving this division the analyst may employ whichever of two basic methods is best suited to his material. When the process of analysis begins with a single entity which is to be divided into its parts, the operation

[1] Edwin E. Slosson, *Creative Chemistry*, 1930, pp. 6-7. Used by permission of Appleton-Century-Crofts, Inc.

is known as *partition*. When the starting point is a number of cases which are to be divided into groups, the process is known as *classification*.[2]

A. Partition

Partition, the division of a whole into its parts, may be a physical process applied to an object or structure or a theoretical process applied to a concept. A physical division is effected, for example, when a derrick is divided into mast, boom, and tackle; a tooth into pulp, dentine, and enamel; a compound microscope into eyepiece, tube, adjusting screw, objective lens, table or stage, and illuminating mirror. Through the use of technical processes, much finer divisions are possible, such as the division of plant or animal tissue into cells, which in turn have still smaller structural divisions discernible under a high-power microscope.

While partition as applied to concepts is abstract, it performs the same function as physical partition, in that it divides the whole into its elements so that they can be studied and worked with separately. Examples of partition as applied to concepts are to be found in the division of color into shade, hue, and intensity; of a musical tone into intensity, timbre, and pitch; and of a force into magnitude and direction. The consideration of different aspects of a single subject may be regarded as a variation of the theoretical or abstract type of partition. Thus a novel may be treated analytically first as a literary work, second as a revelation of the author, third as a social document.

Partition may be illustrated diagrammatically by the division of a circle into segments, a block into sections, or a central trunk into branches. Some such graphic device may aid the student in applying the principle of partition to a plan, a problem, a process, or a literary or artistic composition. This analytical habit of mind is widely use-

[2] There is some divergence among different writers in the application of the terms *analysis, division, partition,* and *classification.* Usage regarding these terms differs particularly in logic and in composition and rhetoric. Indeed, a distinction is sometimes made between *logical analysis* and *expository* (rhetorical) *analysis.* In this text we have followed the usage favored by numerous authorities in composition of treating partition and classification as methods of analysis. Classification in this sense, the division of a group into classes, is, of course, closely related to the process of taking an individual entity and placing it in its class. (See the discussion of definition in Chapter 3.)

ful. Not only is partition used in all fields of science, but, as one logician has noted, "Partition is employed by the builder in laying out his work; it is indispensable to the playwright in fashioning his plot; it is an aid to the lawyer in drawing up his brief, to the orator in marshaling his argument, to the painter in balancing his composition, and to the musician in apportioning his theme." [3]

B. Classification

Classification is the dividing of a group into homogeneous classes. Many classifications have become fixed in the theory of science, such as the botanical and zoological classifications of plants and animals. (See Appendix A, p. 400.) In the applied sciences much research consists of classifying experimental results and accumulated data. For instance, after forty-one years of manufacturing automobiles, General Motors in an engineering report classified auto noises into seven groups: squeak, scrape, grind, rattle, thump, knock, and hiss.[4] Some classifications, like this one, are useful to a specialized group. Others have become a part of general knowledge.

A close relationship exists between dividing a group into classes, or *classification,* and placing a term in its class and then distinguishing it from other members of the class, or *definition.* This relationship is clearly indicated in the following example which proceeds through a classification of particles to a definitive distinction between colloids and true solutions.

> . . . it is evident that there are three very broad classifications of particles in respect to size: (1) those easily visible to the unaided eye, such as raindrops or sand; (2) those which cannot be distinguished even in powerful optical microscopes, exemplified by very fine fogs and some types of clay; and (3) molecules of a substance like water or sugar. We are chiefly concerned with particles belonging to the second group. Any substance existing in the form of particles so small that they will not settle out of a solution is called a *colloid,* or is said to be in the *colloidal state.* The molecular particles of group (3), on the other hand, form what are designated as "true solutions." [5]

[3] Thomas Crumley, *Logic: Deductive and Inductive,* New York, The Macmillan Company, 1947, pp. 85-86. Used by permission of The Macmillan Company.

[4] *Newsweek,* 34:71, September 12, 1949.

[5] Reprinted from *Small Wonder* by Gessner G. Hawley, by permission of Alfred A. Knopf, Inc.

1. Principles of Classification

Classification proceeds ideally according to well-recognized principles.

1. A single basis of division should guide the grouping of individuals into classes at any one stage of the process.
2. The classes should include all individuals subjected to the classification.
3. The classes should be mutually exclusive, that is, should not overlap.

A simple illustration of the first of these three principles may be drawn from everyday practice in classifying houses. It is useful at times to classify houses according to material into brick, stone, and frame houses; according to architectural style into colonial, French provincial, Tudor, English cottage, etc.; according to the accommodations provided into one-family, duplex, and apartment houses. These classifications are correct according to the first principle because a single criterion is used each time to establish the points of division. It would not be correct, however, to divide a group of houses into brick houses, duplexes, and English cottages, because such a classification would have more than one basis of division.

It would be virtually impossible to make a classification of houses which would observe the second and third as well as the first of the three principles. To include all houses in the classification, in accordance with the second principle, would be impossible since some houses would be too individualistic to find a place in any class. To prevent overlapping, in accordance with the third principle, would likewise be impossible since some houses, for example houses of a hybrid architectural style, would share characteristics of two or more classes. Incomplete and imperfect classifications, such as those which can be made of houses, often have great practical usefulness (in setting up insurance or zoning requirements, for example), even though they cannot attain the ideal. However, even when the ideal cannot be attained in a classification, it should be approximated as nearly as possible.

The scientist whose purpose is to reduce natural phenomena to an orderly system encounters many difficulties in endeavoring to make his classifications as nearly complete and perfect as possible.

The difficulty in classifying the duckbill platypus, for example, has made it a zoological curiosity. It has a beak and webbed feet and lays eggs—characteristics which would classify it as a bird. It also shows reptilian characteristics, such as poison spurs which suggest the fangs of a snake. Nevertheless, zoologists, applying the accepted criterion, have classified this furry little animal as a mammal because it suckles its young.

Problems comparable to those of the zoologist arise whenever a comprehensive classification is attempted. The following account, written from the soil scientist's point of view, stresses the importance of classification, the difficulties encountered in preparing classifications, and the necessity of revising classifications to accommodate new discoveries and new materials.

> It is obvious that some sort of soil classification is essential, since the world has a great many thousands of kinds of landscapes, kinds of soil profiles, and kinds of mineral-organic cycles. Of course, one cannot deal with all of these at one time, nor do they present equal contrasts. Actually, there are few sharp lines between soil types; rather the soil of the world is a continuum that may be divided into reasonably homogeneous units according to the state of our knowledge, and the demands for accuracy and scientific prediction. The soil is a natural product, and no two soil profiles are identical any more than two oak trees or two college professors are. Soil types are man-made creations. In one soil type are included all the soils that appear to have the same kind of profile, even though they are not alike in every single respect.
>
> This is not the place to go into the age-old problem of classification. All the natural sciences have the same problem. A classification is good to the extent that it serves the purpose of remembering characteristics, seeing relationships, and developing principles. A classification is bad to the extent that scientists become slaves to it, and twist their data and ideas to fit the classification. It improves as our knowledge grows. Some wonder when soil classification will "settle down"—when names and definitions will no longer be changed. This will happen when soil science has ceased to discover anything new—in other words, when it dies.[6]

2. Patterns of Classification

While all classification results in the division of the entire group into classes, there is a distinction between the pattern or arrangement

[6] Charles E. Kellogg, "Modern Soil Science," *American Scientist*, 36:526, October 1948.

arrived at by a division into two classes and that arrived at by a division into more than two classes. Division into two classes on a positive-negative basis is known as *dichotomy*, which means a cutting in two. For example, according to the presence or absence of a single attribute, motions may be classified as voluntary or involuntary, actions as legal or illegal, fruits as edible or inedible. Such a dichotomous division may have great practical utility when one attribute is of paramount importance. It may, for instance, be desirable for one purpose to classify metals as ferrous and nonferrous, for another purpose as critical or noncritical.

A simple dichotomous division, however, is less satisfactory for many purposes than a division into a larger number of classes. For example, division of individuals into age groups according to those over forty and those under forty would serve few purposes, though a categorical division into infants, children, adolescents, etc., is generally useful. In preparing such a categorical classification, the differentiating factors on which the division is based, such as time, place, physical differences, must be selected with care. Then the classification must be completed according to one differentiating factor before another is introduced. Since the scientist often has to classify material which is exceedingly complicated, the setting up of significant categories depends upon the ability to recognize significant likenesses and differences.

In order to learn all he can from his data, the scientist may find it desirable to classify them several times, each time setting up the categories on the basis of a single differentiating factor. In setting up a classification, the classes formed on the basis of one factor may become the main division and those formed on the basis of another factor the subdivisions. For example, arrests made during a certain period might be classified according to the sections of the city in which they occurred; then each of the classes might be subdivided according to the nature of the offense.

A study of cancer cases[7] illustrates the advantage of classifying data under different sets of categories so that comparisons may be made and conclusions drawn. In this study 531 cases were tabulated

[7] Howard C. Taylor, Jr. and Walter F. Becker, "Carcinoma of the Corpus Uteri," *Surgery, Gynecology, and Obstetrics*, 84:129-39, February 1947.

according to such factors as age of patient, duration of symptoms, histologic type, and method of treatment, as well as end results. This analysis permitted the study of the relationships between these different factors and the end results.

III. PRESENTATION OF ANALYSIS

In addition to graphic and pictorial means of presenting analysis (see Chapter 15) there are two forms of presentation, tabular and outline, which employ verbal headings. A study of analytical tables and outlines furthers an understanding of analysis because these means present analysis in skeleton form. Tables are used principally to show classifications of data. Outlines may be used to show either classifications or partitions within a paper or the structure of the paper as a whole. The paper, of course, may present the analysis in amplified form together with a discussion of the material and an interpretation of its significance. (See Section IV.)

A. Tabular Form

Tabular presentations of material usually follow a columnar arrangement with one set of variables listed in the column at the left and another set expressed in the headings of the remaining columns. The first of the following examples is a relatively simple though comprehensive table which shows the applications of the terms large, medium, and small at different size levels. The size levels, numbered and listed at the left, are arranged in descending order.

Summary of Size Levels [8]

Level	*Large*	*Medium*	*Small*
1. Celestial	Nebula	Star	Planet
2. Geographic	Earth	Island	Mountain
3. Ocular	Skyscraper	Football	Sand grain
4. Microscopic	Bacteria	Blood corpuscle	Fat globule
5. Colloidal	Rubber particle in latex	Carbon black particle	Protein molecule
6. Molecular	Cellulose	Sugar	Water
7. Atomic	Atom	Electron	Proton

[8] Hawley, *op. cit.*, p. 35.

The next table shows "the relation of smallpox morbidity to vaccination laws in the United States during the period 1919-1928." Here analysis almost anticipates interpretation, since, as the author notes, the figures tell the "tale more graphically than any polemic. The incidence per 100,000 of the population is in direct proportion to the kind of law operating."

Relation of Smallpox Morbidity to Vaccination Laws in the United States, 1919-1928 [9]

Vaccination laws	*Number of states **	*Population*	*Number of cases*	*Incidence per 100,000*
Compulsory vaccination	10	32,434,954	21,543	6.6
Local option	6	17,930,882	91,981	51.3
No vaccination laws	29	59,923,117	393,924	66.7
Compulsory vaccination prohibited	4	4,002,888	46,110	115.2

* Including the District of Columbia.

B. Outline Form

The outline is an excellent device for showing either a classification or a partition. In an outline intended to show a partition the main headings indicate the principal segments of the whole.

The following partitive outline of John H. Skinkle [10] is preceded by a statement indicating the exact structure partitioned.

> The pendulum tester is the type in common use for all textile materials. . . .
>
> The pendulum tester consists of three main parts:
>
> I. Straining mechanism
>   A. Constant speed motor, gear train, nut, and screw; **or**
>   B. Cylinder and piston, with hydraulic pressure
> II. Jaws or clamps holding the specimen
> III. Loading and recording mechanism
>   A. Chain
>   B. Drum
>   C. Pendulum arm and weight

[9] I. Bernard Cohen, *Science, Servant of Man*, Boston, Little, Brown and Company, 1948, pp. 300-01.

[10] John H. Skinkle, *Textile Testing*, Brooklyn, Chemical Publishing Company, Inc., 1949, p. 148.

D. Pointer and scale
E. Notched sector and ratchet
F. Autographic stretch-load recorder

Another example of a partitive outline, taken from *General Biology*,[11] also shows a statement of the structure to be partitioned.

> A well-developed muscular system is present in the earthworm. Its main parts are as follows:
>
> I. Muscles of the body wall
> A. Circular; outer layer, which constrict and lengthen the body
> B. Longitudinal; inner layer, which shorten and thicken the body
> II. Muscles of intestinal wall, thin layers between lining epithelium and chloragen cells
> A. Circular, within, which constrict the intestine
> B. Longitudinal, without, which shorten the intestine
> III. Muscles of setae
> A. Protractors, which protrude the setae from their sheaths
> B. Retractors, which draw the setae into their sheaths

In an outline intended to show a classification, the main headings indicate the chief classes or in some instances the principles according to which the material is classified. For example, if material is classified three times, once according to time, once according to place, and once according to use, the three headings would be built around the terms time, place, and use. The subheadings show the divisions within each class, or, if the main headings express principles, the classes derived by applying each principle.

The first classificatory outline reprinted here presents the classification of "the sources of water available in the hydrologic cycle." [12]

I. Rain and snow
II. Surface water
A. Streams
B. Natural ponds and lakes
C. Impounding reservoirs
III. Ground water
A. Springs
B. Shallow wells and infiltration galleries
C. Deep wells

[11] Leslie A. Kenoyer and Henry N. Goddard, *General Biology*, New York, Harper & Brothers, 1945, p. 212.

[12] *Water Quality and Treatment*, 2nd ed., New York, American Water Works Association, Inc., 1950, p. 1.

The second classificatory outline is accompanied by the author's introduction which explains the coverage and basis of the classification.

Why Do People Write Personal Documents? [13]

The following outline summarizes the forms in which personal documents are found. The many varieties of *third-person* case studies, life histories, interview-reporting, psycho-portraits, biographies, institutional records, etc., are not included, for it is only with first-person documents that we are here concerned.

I. Autobiographies
  A. Comprehensive
  B. Topical
  C. Edited
II. Questionnaires
III. Verbatim Recording
  A. Interviews
  B. Dreams
  C. Confessions
IV. Diaries
  A. Intimate Journals
  B. Memoirs
  C. Log-Inventories
V. Letters
VI. Expressive and Projective Documents
  A. Literature
  B. Compositions
  C. Art Forms
  D. Projective Productions
  E. Automatic Writing
  F. Various

The faults of outlines prepared by inexperienced writers to show classification frequently arise from an illogical or incomplete classification, as in the following example submitted by a student.

DEFENSE MEASURES IN SNAKES

```
I.    Protective positions
      A. Balling
      B. Freezing
      C. To play dead
II.   Uses of tails
      A. Some snakes are
         shield-tailed
      B. Mimicry
III.  Expanding body and
      head
IV.   Contortion
V.    Noise-making
      A. Hissing
         1. Russell's
            viper
      B. Scale-rubbing
      C. Rattling
VI.   Speed
VII.  Protective habitats
      A. Burrowing snakes
      B. Arboreal snakes
      C. Aquatic snakes
VIII. Biting
      A. Nonpoisonous
      B. Poisonous
      C. Fang types
IX.   "Spitting" poison
X.    Coloration
```

[13] Gordon W. Allport, *The Use of Personal Documents in Psychological Science*, New York, Social Science Research Council, Bulletin 49, 1942, p. 67.

The inadequate classification in the preceding outline is apparent in the large number of main topics and in the raising of such minor points as "Spitting" poison to equal rank with more general headings. A single subtopic such as the one occurring under A of section V is regarded as a flaw in an outline since any section divided must be divided into at least two parts. This comment applies particularly to partition. Occasionally a single subtopic is unavoidable in classification if certain classes contain only one member.

As frequently happens, inconsistencies in logic are accompanied in the outline by inconsistencies in form. Co-ordinate topics are not expressed in parallel grammatical form, particularly gross errors being the co-ordination of the infinitive with two gerunds under heading I, and of the sentence with the noun under heading II.

The revised form of the outline incorporates corrections of the most conspicuous faults in the original.

```
DEFENSE MEASURES IN SNAKES
        (Revised)

  I. Protective charac-
     teristics
     A. Shield tail
     B. Fangs
     C. Coloration
     D. Speed
 II. Protective positions
     A. Balling
     B. Freezing
     C. Playing dead
III. Protective behavior
     A. Body movement
        1. Expansion
        2. Contortion
     B. Mimicry
     C. Noise-making
        1. Hissing
        2. Scale-rubbing
        3. Rattling
     D. Biting
        1. Nonpoisonous
        2. Poisonous
     E. "Spitting" poison
 IV. Protective habitats
     A. Burrows
     B. Trees
     C. Bodies of water
```

IV. FUNCTION OF ANALYSIS IN PLANNING THE PAPER

Many writers have a theoretical understanding of analysis without appreciating the function of analysis in the planning of a paper. Just as the scientist has been able to organize large bodies of knowledge by means of partition and classification, the writer can employ analytical methods in organizing the materials of his paper. The plan of every paper which follows a logical rather than a chronological pattern depends in part upon analysis. Even a chronicle of

events is analytical to the extent that the events are grouped into steps, periods, or phases. The purpose of many expository papers is primarily analytical. Reports of surveys, for instance, consist largely of a classification of the findings. Reports of experimental research often present the results in classified form. Other papers present the subject in its parts or aspects and hence are essentially partitions. If an expository paper is not analytical in purpose, the author must at least classify or group his ideas, usually through the use of an outline.

When the problem under investigation is carefully formulated, the process of analysis begins before the data are studied, or even before they are collected. If, for example, the purpose of an investigator is to study the effect of sugar on the teeth of a certain group of children, a categorical division of the children according to the amounts of sugar in their diets is implicit in the problem. On the other hand, records already available may be made the means of studying a variety of problems. Thus if an investigator has available for analysis the complete records of a group of university students, he may make cross tabulations according to age, sex, grades, etc. Such groupings will serve the same purpose as if he had been able originally to select comparable groups of students for study.

A. Analytical Treatment of Subject Matter

The precise place of analysis in the planning of a paper depends upon whether the paper deals primarily with data from the writer's own investigations or with the findings and conclusions of other writers.

If the investigator begins with raw data, such as measurements, vital statistics, replies to questionnaires, he must classify them before he can draw his conclusions and organize his paper. This process of classification consists of setting up meaningful categories and distributing the data accurately among the categories so that the number in each class may be counted. The writer who is describing an object or structure is likely to rely directly on partition; the divisions of the object or structure into parts will suggest the divisions of the paper.

The writer who is dealing with a variety of materials, part of them more or less assimilated by previous writers, often finds it difficult

to make a start in organizing his paper. Here a consideration of the relative advantages of partition and classification will often be helpful. Is the subject matter chiefly material to be classified or an entity to be considered in different aspects?

One student, for example, planning a paper presenting material he had accumulated in his casework with children, wished to emphasize the case of one particularly self-centered and introspective child. His difficulties in organizing the paper were greatly lessened when it was suggested that he could either make it primarily a case study of the one individual, introducing other material as background, or arrange the cases in groups, giving prominence in the discussion to those he considered of greatest interest. The first choice would, of course, represent a partitive plan, the second a classificatory plan.

The reporting of some studies will demand a more complex plan of attack. The author of one paper dealing with the diabetic school child, for instance, chose to center the study on the child, partitioning the paper into the principal aspects considered—physical characteristics, heredity, environment, special difficulties, and care. Some of these topics were in turn made the headings of such classifications as physical and emotional difficulties. It must be remembered, however, that while the experience of other writers may be helpful, the planning of each paper involves individual problems in analysis which the writer must resolve in organizing his material.

B. Formal and Informal Analysis

Formality in analysis implies relative completeness, the use of technical language in designating parts and classes, and close adherence to logical principles. There is a great range in the degree of formality expected of analyses. The range extends from an exhaustive statistical analysis of data which can be measured quantitatively to the simple enumeration of the most important factors in a situation. Analysis directed to the expert is naturally more formal and detailed than that prepared for the general reader. Characterizing analysis as informal does not, on the other hand, imply a hasty, superficial treatment. To the contrary, it implies only a less detailed and less exhaustive treatment, carefully tailored to suit a less than technical audience. And an informal analysis should be no less informative and provocative to its audience than a formal analysis is to experts.

Both the following examples are analytical discussions of the properties of titanium. The first example is definitely informal. It does not attempt a comprehensive discussion of the properties and uses of titanium, but selects those of interest to the general reader. Numerical and technical terms are kept to a minimum.

> Titanium metal offers some new and valuable combinations of properties. . . . It is no all-purpose metal; such metals do not exist. Aluminum, for instance, is light, easily formed and machined, but it has relatively low strength and some bad corrosion problems. Stainless steel has high strength and corrosion resistance, but its weight is a handicap for many uses. For certain purposes, therefore, titanium fits right in between the two in engineering use: it is strong, medium weight, corrosion resistant. Its melting point is some 300 degrees higher than iron. While this doesn't give it as high heat resistance as might be expected, titanium retains its strength at moderately elevated temperatures where aluminum and magnesium alloys lose much of theirs.
>
> Paradoxically, titanium's great affinity for oxygen benefits the ductile metal. Upon its first exposure at room temperature, it acquires an impenetrable (but invisible) oxide coating, which protects it from the atmosphere, salt water, and most acids (excluding, principally, sulfuric and hydrochloric). In a series of tests, titanium endured, without harmful effect, 600 hours of exposure at 190° Fahrenheit to fruit juices, onion in water, vinegar, lard, tea, coffee, and lactic acid. Corrosion resistance is at present titanium metal's most important property.[14]

In contrast to the preceding example, the following example is relatively formal and presents a detailed and technical discussion of the properties of titanium and their relation to its uses.

> *Potential Uses for Titanium Metal.* Titanium has many actual and potential uses, based for the most part upon its properties as a silvery white, light, corrosion-resistant, tough, strong metal. Among the metals available for construction there is a gap between aluminum and steel. Aluminum, with a desirably low density of 2.7, is easily formed and machined, but it has relatively low strength and is not resistant to corrosion. Iron, at the other extreme, can be alloyed to give high strength and resistance to corrosion, but its greater density, 7.87, is a decided disadvantage where weight is an important factor. Titanium, with a density of 4.5, coupled with its strength, ductility, high melting point, and noncorrosive characteristic, is the present outstanding candidate to fill this gap. It combines the properties of stainless steel with

[14] "Titanium: the New Metal," *Fortune*, 39(5):123, May 1949.

those of the strong aluminum alloys and possesses certain definite advantages over both. One outstanding advantage is its high proportional limit which is comparable to that of heat-treated steels and aluminum bronze, while its density is only a little over half that of these materials. As a result, wrought titanium is in a class by itself so far as the weight of a section having a given proportional limit is concerned. Titanium would be a preferred structural material in aircraft design where a minimum weight combined with a continued high stress is important. Its resistance to corrosion would be an added advantage in airships for use over the sea or along the coast. A potential use of great importance is for making reciprocating mechanical parts in jet engines where heat and pressure are great. The metal seems almost ideal for ocean-going vessels because of its outstanding properties of lightness, strength, and great resistance to corrosion. As the cost of production is decreased, titanium will be used extensively for structural purposes. Even at the present high price it should find use in all sorts of diaphragms that are maintained under tension, particularly in microphones where weight is important. Titanium seems well suited for textile machinery where a considerable saving of power can be effected by using such a light, strong metal for high-speed spindles, spools, warp beams, and other moving parts. It does not stain the threads as do aluminum and magnesium alloys. Another of the important uses of the future is in suspension-bridge cables. These properties of titanium may prove important in the eventual utilization of atomic energy.

The surface-hardening property of titanium gives it a definite advantage over the really light metals in the construction of parts subject to frictional wear. It seems suited for automobile pistons, because, in addition to the characteristic properties of lightness and strength, it has a coefficient of expansion a little less than that of cast iron that is ordinarily used for cylinders. The high heat conductivity suggests its use for handles for aluminum pans and cooking utensils. It has been proposed for many sports uses, such as tennis rackets and fishing rods, where its excellent physical and working properties would be utilized. Combination of stainlessness, high proportional limit, and low modulus makes it an ideal material for springs, and its use should make possible the construction of greatly improved spring balances and watch springs. Its properties also recommend it for use in tool mountings where a certain amount of give is desirable to prevent breakage, and in making pen points and styluses. X-ray diffraction tubes with titanium targets are in the development stage. Rubbing titanium metal against a hard surface often produces a smear which is difficult to remove, and this characteristic is employed for a variety of purposes, including the production of very stable high electrical

resistance glass, simply by marking the surface with a titanium point. Such smears can be used to coat materials with a metallic film and to etch glass without the use of hydrofluoric acid. Herenguel investigated the use of titanium powder as a paint pigment.

The really large-scale use of titanium seems to depend only on its availability in suitable form at a price in line with the common metals such as iron and aluminum. It would be a notable exception to technological progress if titanium, with such desirable properties, failed to be an important engineering metal of the future. It is hoped that this book will encourage research on the production of low-cost titanium metal.[15]

V. APPLICATIONS OF ANALYSIS

The use of analysis antedates modern science. The ancient Greeks particularly were of a highly analytical disposition. Aristotle, whose *Rhetoric* has been called a feat in analysis, drew many distinctions in poetry, in philosophy, in science—distinctions which have ever since influenced, and perhaps at times inhibited, thought. However, analysis is today closely associated with science because it has been constantly employed in the organization of scientific knowledge and is fundamental in scientific procedure. Science students will readily think of examples from their own fields: botanists of monocotyledonous and dicotyledonous plants; geologists of igneous, sedimentary, and metamorphic rocks; bacteriologists of aerobic and anaerobic bacteria.

The applications of analysis are today undergoing rapid expansion and development. Many of these developments lie in two areas: the use of analysis, particularly advanced statistical analysis, as the basis of prediction; and the co-operative application of analysis to practical problems in business, industry, and military operation.

A. Analysis and Prediction

The ability to predict the future has long been recognized as a test of scientific validity. On the basis of successful predictions, hypothesis becomes a theory, and the theory an accepted principle. Some time may elapse before all the discrepancies between fact and theory are successfully accounted for. This process may be illustrated

[15] Jelks Barksdale, *Titanium*, New York, The Ronald Press Company, 1949, pp. 52-54.

by the experience of chemists with the Periodic Table. This table, which lists the elements according to their atomic weights and arranges them in groups having similar properties, is considered a major achievement in the classification of natural phenomena. When Mendelyeev constructed the table in the 1860's he left blanks at certain points, thus predicting the existence of elements then unknown, some of which were later discovered. One difficulty which arose, however, was that some elements appeared to have more than one atomic weight. This discrepancy was not accounted for until the work on isotopes in the first quarter of the twentieth century.

Predictions made on the basis of analysis should not, of course, be confused with the process of analysis itself. However, analytical methods have proved so successful in determining probabilities that their use is constantly being extended. Even in literature analytical study has led to successful predictions.

> Some thirty years ago, a student of the Germanic languages, reading over an Old English poem of considerable length, called the *Genesis*, was struck by the fact that five or six hundred lines, in the heart of the poem, seemed to differ in various respects from the lines which preceded and followed. Pursuing his inquiry further, and comparing the forms of these lines with those of a kindred language, he came to the conclusion that this section, which had always been supposed to be the original Old English, had been in fact translated from Old Saxon, the continental Germanic tongue referred to above, and was therefore led to believe in the existence of an Old Saxon poem on this subject of Genesis, though he was obliged to confess that he had found no other trace of its existence. Some twenty years after, another scholar, at work in the Vatican Library, which had only recently rendered its treasures more accessible, discovered a fragment of the missing Old Saxon *Genesis*, of which probably no one had read a line for a thousand years. Yet such had been the faith of competent scholars in Sievers' processes that no one was surprised when the missing manuscript swam into sight, any more than astronomers were amazed when the telescope pointed to the quarter of the heavens indicated by Adams and Leverrier, and revealed the planet Neptune, which no human eye till then had ever seen. Professor Sievers might have read histories of Old English literature, and essays on it, for decades; he might have read this poem in a casual way a score of times, just as Adams and Leverrier might have rushed about the sky with their telescopes for unnumbered nights, without anything to reward their diligence; but by the intensive methods they actually

employed, Sievers became famous at twenty-five, and Adams immortalized himself at twenty-seven.[16]

At the opposite extreme from such a relatively simple example are the large-scale applications of statistical analysis to a great variety of problems. The theoretical basis of some of these statistical techniques and their application in insurance and in the telephone industry, as well as in investigating certain scientific problems, are explained in Appendix A, p. 403.

B. Analysis and Practical Problems

In other rapidly developing applications of analysis, the point of emphasis is on the problem to be solved rather than on prediction. In this category fall *content analysis*, which attacks the problem of evaluating the accuracy of mass media of communication, and *job analysis*, which attacks the problem of fitting the capabilities of the individual to the requirements of the job.

The specialized field known as operations research developed rapidly during World War II because of the centering of many scientific minds on the problems of improving military operations. The term *operations research* has been defined as "a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control." [17]

Up to the present time many of the applications of operations research have been military, but the following example illustrates its usefulness in business.

> In one analysis of a mail order concern, selling extensively to low-income rural families, it was discovered that there was a sharp dependence of COD refusals on time between the writing of the original order by the family and the delivery of the item by the mailman. Evidently, in this case, there was a "mean free time" of ready cash in such families, whether because of other financial pressures or impatience or simple shortness of memory. If the item ordered did not arrive within a certain time, the money was spent somewhere else and the COD item had to be refused. From this simple observation came

[16] Albert S. Cook, *The Higher Study of English*, Boston, Houghton Mifflin Company, 1906, pp. 75-76.

[17] Philip M. Morse and George E. Kimball, *Methods of Operations Research*, New York, published jointly by the Technology Press of Massachusetts Institute of Technology and John Wiley & Sons, Inc., 1951, p. 1.

a reorganization of selling methods of the firm, resulting, incidentally, in considerable reduction in such lost sales.[18]

Analysis has its limitations. To analyze a problem is not necessarily to solve it, as we are reminded by the title of a government report published in 1919, "Analysis of the High Cost of Living Problem." Analysis yields its greatest successes when it is used not alone, but in conjunction with interpretation and synthesis. Nevertheless, when all the past achievements and future promises of analysis are taken into account, one finds increasingly significant the statement of Sir Arthur Eddington, "For a scientific outlook I think the most fundamental of all forms of thought is the concept of analysis."[19]

STUDY SUGGESTIONS

1. Prepare a classificatory outline on one of the following topics: motor vehicles, air-conditioning units, types of central heating, textile fibers, orchestral instruments, halogens.
2. Prepare a partition outline on one of the following topics: a condenser, a telephone switchboard, a business letter, an individual halogen such as iodine, the human ear.
3. Show how the contrasting methods of classification and partition may be used in an analysis of each of the following: human teeth, methods of research, university organization, the sales tax, flammability of fabrics.
4. Discuss the proposition that the whole is often equal to more than the sum of its parts.
5. Explain the difference between treating a situation or problem "descriptively" and treating it "analytically."
6. Can you give instances of predictions which were based on analysis and which were later verified?
7. William P. D. Wightman has said of the work of Josiah Willard Gibbs, "Gibbs' first contribution to knowledge was to show that far wider consequences could be drawn from curves showing the relation between volume and *entropy*. . . . His great powers of geometrical imagery enabled him to introduce a third variable, energy, whereby thermodynamical *surfaces* instead of curves were generated. By the analytical manipulation of these surfaces Gibbs was able to break entirely new ground in the application of thermodynamics." (*The Growth of Scientific Ideas*, New Haven, Yale University Press, 1951,

[18] *Ibid.*, p. 6.

[19] Sir Arthur Eddington, *The Philosophy of Physical Science*, Cambridge, Eng., Cambridge University Press, 1939, p. 118.

p. 294.) Through library reading, inform yourself further concerning Gibbs' contributions to physical science and show the importance of analysis in Gibbs' work on the criteria of equilibrium and the Phase Rule as well as in that on the thermodynamical surfaces.

8. Prepare a list of practical problems of current concern which might be studied by analyzing each problem and then enlisting the aid of experts to concentrate on its elements.

CHAPTER 6

INTERPRETATION: APPLYING THE PRINCIPLES OF LOGIC

On all questions where his passions are strongly engaged, man prizes certitude and fears knowledge. Dispassionate inquiry is welcomed only when the result is indifferent. J. W. N. SULLIVAN, Aspects of Science.

It is a delusion that the use of reason is easy and needs no training or special caution. W. I. B. BEVERIDGE, The Art of Scientific Investigation.

I. LOGIC AND THE SCIENTIFIC WRITER

Philosophers and scientists have frequently questioned whether scientific investigation is actually as indebted to logic as it is assumed to be. One modern philosopher, F. C. S. Schiller, placed high among "the obstacles to scientific progress" the analysis of scientific procedure which logic has provided. W. I. B. Beveridge in *The Art of Scientific Investigation* quotes, with approval, Schiller's comments

and others in similar vein and stresses the importance in research of imagination, intuition, observation, and chance, as well as reason. This divergence in viewpoint between the scientist and the logician exists partly because the scientist centers his work on observations of material phenomena, while the work of the logician emphasizes the framing and testing of verbal or formal propositions. However, each has much to learn from the other, and it is the purpose of this chapter to show the usefulness of the principles of logic to the scientific writer in interpreting his data.

Within the past hundred years modern logic, like modern science, has undergone rapid development. Emphasis on the logical determination of probability has replaced the emphasis of earlier times on formal proof. Another development has been the rise of symbolic logic, which represents an endeavor to get away from verbal pitfalls by devising logical formulas which can be manipulated somewhat like the formulas of mathematics. Symbolic logic is, however, an extremely complex subject, and the writer who is not a specialist in logic must still depend on verbal expression of logical principles, mindful, of course, of the difficulties which arise from the tendency of words to shift their meanings according to context.

A. Logic in Planning and Reporting Research

Experimental method involves expressing a theory as a logically framed statement and then conducting tests to determine whether the proposition is true or false. For instance, chemical tests for properties presuppose the framing of such hypothetical propositions as "this unknown substance is an acid" or "this unknown substance is a base." By the use of other propositions known to be true, such as "acids turn litmus paper red," "bases turn litmus paper blue," procedures may be employed to test the truth of these hypothetical propositions. The same principle of setting up a hypothesis—that is, a tentatively accepted theory—and then subjecting it to test is used in designing much more complex experiments.

When results of research are reported, the plan of the ensuing paper takes on a logical sequence which may not have been evident at all stages of the investigation. As Hans Reichenbach has observed, the "actual process of thinking evades distinct analysis. . . . We connect logical analysis, not with actual thinking, but with thinking in

the form of its rational reconstruction." [1] In like manner, the scientific report is a rational reconstruction of a scientific investigation. The report disregards the false starts, "hunches," and errors that may have occurred during the course of the investigation.

B. Errors in Reasoning

The theory of logic as it has been developed in the past embodies the description and classification of fallacies or errors in reasoning. The term *fallacy* is not applied in strict usage to a mere mistake or illusion but only to an error in reasoning. Fallacious reasoning is most dangerous when it appears outwardly to be most logical.

II. INTERPRETATION

From the time the writer first conceives his problem, there is no point at which he can ignore logical considerations. In any investigation it is essential to distinguish between the data collected, the background of fact and theory on which the writer relies in interpreting these data, and the inferences and conclusions drawn from the data. And both data and inferences must be distinguished from unsupported expressions of opinions.

A. Distinguishing Among Data, Inference, and Opinion

The term *data* refers specifically to the investigator's own findings in the course of his study. The word *data* (singular *datum*) means literally the things given. Bertrand Russell has observed: "The question of data has been, mistakenly as I think, mixed up with the question of certainty. The essential characteristic of a datum is that it is not inferred." [2] For example, a statement made to an interviewer may or may not be true; but true or false, the statement as made and accurately recorded forms a part of the interviewer's data, and properly interpreted, may legitimately be made the basis of inference.

The essential characteristic of an *inference* is that it is derived not from observation or memory but from reasoning on the basis of accepted data, sometimes less specifically termed "the facts." For example, records may show that a supporting metal bar has repeatedly

[1] Hans Reichenbach, *Elements of Symbolic Logic*, New York, The Macmillan Company, 1947, pp. 1-2.

[2] Bertrand Russell, *An Inquiry into Meaning and Truth*, New York, W. W. Norton and Company, Inc., 1940, p. 155.

given way under stress. It may be justifiably inferred that the bar is not strong enough to support the weight to which it is subjected. An inference must be based on reliable data and be logically sound if it is to be used in arriving at more general conclusions.

Opinion must be sharply distinguished from inference. An opinion represents a personal judgment; it is not necessarily based on reason and evidence. For example, one could be of the *opinion* that seeds grow better if planted in the dark of the moon; on the basis of evidence and reason, one must infer that rates of growth are determined by other factors. It is futile to argue questions which can be settled by reference to factual evidence. In such areas as philosophy, religion, and politics, opinions are difficult to validate by evidence based on observation and tend to be influenced by emotional or cultural bias. In areas where evidence is not conclusive, the value of an opinion depends on the competence of the person expressing it and the process by which he arrived at it. Nevertheless, many readers accept quoted opinion as valid without examining its origin or the evidence behind it.

B. Relationships Among Data, Analysis, and Interpretation

An investigation of a problem, when broken down into its parts, proceeds from the collecting of data to the analysis of data and thence to interpretation. In actual practice, however, the investigator is constantly drawing inferences, and even the most elementary observations involve some interpretation. For example, a layman on a country walk may pick up a rock which he considers unusual; to a geologist the same rock may be an addition to his collection of geodes. The natural phenomenon is the same in both cases—both men have classified the rock on the basis of inference—but the geologist's training enables him to classify and interpret his sensory impressions more meaningfully. Continuous interpretation in the light of training and experience accompanies all our observations. As Eddington has put it, "We shall probe down towards the roots of knowledge; but the most primitive data we can reach will not be wholly independent of the primitive forms of thought. We just cannot help being brainy, and must try to make the best of it." [3]

[3] Sir Arthur Eddington, *The Philosophy of Physical Science*, Cambridge, Eng., Cambridge University Press, 1939, p. 195.

Moreover, an investigator throughout his research project considers the significance of results he has already obtained and relates them to his previous knowledge.

> If we understand by interpretation the establishment of a link between the results of a study and other pertinent knowledge—that is, the search for broader meaning—it would be uneconomical, and indeed often impossible, to make interpretation the last crowning step of an inquiry. The search for such links is a continuous preoccupation of the social scientist during the entire course of an inquiry; in particular, interpretation is often inextricably interwoven with the process of analysis.[4]

From these considerations it follows that if final conclusions are to be valid, the logical sequence from data to inference must be established at every stage of the inquiry.

III. INDUCTIVE REASONING

Logically there are two methods of drawing inferences from accepted facts or data; these methods are known as *inductive* and *deductive reasoning*. Inductive reasoning proceeds from a number of observations to a conclusion or general principle, that is, from the particular to the general. Deductive reasoning—the method of formal proof familiar in geometry—proceeds from an established principle to its application in individual instances, that is, from the general to the particular.

A. Meaning of Inductive Reasoning

Scientific induction may be regarded as a refinement of folk practice in learning from experience. Many popular inductions are expressed in rhymes and adages. For example, the saying "Evening red and morning gray sends the traveler on his way; evening gray and morning red sends the traveler wet to bed" expresses the popular induction that clouds in the morning are a less serious portent of rain than clouds in the evening. Scientific inductions may likewise be derived, with proper precautions, from experience, including the observation of controlled experiments.

[4] Marie Jahoda, Morton Deutsch, and Stuart W. Cook, *Research Methods in Social Relations, Part One*, New York, The Dryden Press, Inc., 1951, p. 255. Reprinted by permission of The Dryden Press, Inc.

Among the many inductions which form a part of the whole body of scientific knowledge a few simple examples may be cited: metal expands when heated, altitude affects the boiling point of water, light travels faster than sound, fever or elevation of body temperature is frequently a sign of illness or inflammation, sugar is soluble in water. The term *empirical* is often applied to knowledge based on experience and experiment, as opposed to theory.

B. Fallacies in Inductive Reasoning

Since it is not feasible to examine all the possible instances of a general principle arrived at by a process of inductive reasoning, inductions are regarded as being supported by evidence rather than by absolute proof. As the evidence accumulates, the probability of the correctness of the induction increases until eventually the induction may be accepted for all practical purposes as established.

Fallacies in inductive reasoning occur when a conclusion is accepted as valid on the basis of insufficient evidence, or is drawn from nonrepresentative instances. A single experience with an individual may lead a thoughtless person to conclude that all members of that individual's nationality are dishonest. The instance of dishonesty which is conspicuous because of its rarity may attract attention and lead to a generalization on the basis of an experience which is the reverse of typical. This fallacy of generalizing from insufficient knowledge becomes even more dangerous when the conclusions are extended beyond the group under immediate consideration. For example, a study of a small group of students in one college may become "the drinking habits of the college man," or inferences drawn from observation of a teen-age club in one city may be applied to "modern youth."

The study of groups by means of the "sampling technique" in research has in recent years been greatly extended. Through this technique the attempt is made to postulate the characteristics and potential behavior of a group or a whole, or of parts of the whole, by a study of a relatively small sample. Certain standards must be adhered to if this technique—still undergoing development—is to be successful. These standard precautions are stated explicitly in the government's requirements for samples of uranium ore.

> Samples submitted to the Geological Survey or the Bureau of Mines should weigh at least 1 pound. . . . Each sample should also be a representative one; that is, it should represent, as fairly and accurately as possible, the rocks of the entire deposit from which it was taken. If one part of the deposit appears to be more radioactive than another, rocks taken from both parts should be included in the sample. If a small amount of high-grade ore is submitted, it should be stated that the sample is not representative of the entire deposit, but only of a small portion of it.[5]

These standards—that the sample should be not less than minimum size and should fairly and accurately represent the whole—remain the same whether the sample is taken of a physical substance, as here, or of people and their ideas. Experience in political polls has shown that even a large sample may be misleading if it is not representative. The *Literary Digest* election poll of 1936, for example, went widely astray in spite of the large number of individuals polled because the method of selection from telephone subscribers failed to give a representative cross section of the voting population.

Another fallacy in inductive reasoning is the overextension of analogy. An analogy is a comparison between two things not necessarily alike except in the characteristics or attributes compared. (For a discussion of the rhetorical uses of analogy, see Chapter 7.) In drawing inferences on the basis of analogy it is reasoned that if two things resemble one another in certain respects, they are likely to resemble one another in other respects. An inference based on analogy may be misleading if the resemblance is assumed to be more far-reaching than it actually is.

Theories and hypotheses based on analogy must therefore be considered highly speculative until they have been thoroughly tested. Substances harmless to one individual may, for instance, be toxic to another, results obtained with experimental animals may not be applicable to man, and the species of grapes which succeeds in one region may fail elsewhere.

The uncritical application of analogy leads also to many errors in handling social problems. It is falsely assumed, for example, that methods of handling employer-employee relationships which work in one plant will work in another where conditions are different, that

[5] *Prospecting for Uranium*, United States Atomic Energy Commission and the United States Geological Survey, Washington, D. C., United States Government Printing Office, 1951, p. 40.

methods of discipline successful at school will necessarily be successful at home, that methods of instruction which are effective in one time and place may be used with equal success in another. The value of an analogy as a means of inductive reasoning may be summed up by quoting Rudolf Carnap, who expresses "agreement with the general conception according to which reasoning by analogy, although admissible, can usually yield only rather weak results." [6]

Analogical reasoning or the noting of resemblances has, nevertheless, often been productive of scientific advance. Charles Darwin, for example, was able to formulate his theory of natural selection on the basis of comparisons he had made of myriad forms of plant and animal life. At first he "without any theory collected facts on a wholesale scale," and his theory developed as a result of comparable instances of adaptation which he found.[7]

The goal of much inductive reasoning is to establish general principles based on causal relationships. The relationship between cause and effect is, however, one of the most intricate and difficult of logical problems. One of the commonest fallacies is to assume that because one occurrence follows another closely, the first one is the cause of the second. This fallacy, often referred to by its Latin name—*post hoc, ergo propter hoc* (after this, therefore because of this)—appears in various guises.

> Many popular superstitions are examples of this fallacy. Some project begun on Friday turns out disastrously, and it is inferred that some causal relation existed between the fate of the enterprise, and the day on which it was begun. Or thirteen persons sit down to dinner together, and some one dies before the year is out. It is to be noticed that such beliefs are supported by the tendency . . . to observe only the instances in which the supposed effect follows, and to neglect the negative cases, or cases of failure. "Fortune favours fools," we exclaim when we hear of any piece of good luck happening to any one not noted for his wisdom. But we fail to take account of the more usual fate of the weak-minded.[8]

[6] Rudolf Carnap, *Logical Foundations of Probability,* Chicago, The University of Chicago Press, 1950, p. 569.

[7] A passage from Darwin's *Autobiography* in which he describes his methods and a twentieth century biologist's analysis of Darwin's reasoning appear in Appendix A, p. 405 and p. 406.

[8] James Edwin Creighton, *An Introductory Logic,* 4th ed., New York, The Macmillan Company, 1922, p. 310. Used with permission of The Macmillan Company.

The *post hoc* fallacy has likewise led to many errors in pure and applied science. In the past many medical cures were attributed to the efficacy of the treatment—whether pills and potions or the long-honored practice of bleeding—when the true curative agent was the inherent recuperative power of the body or the self-limiting nature of the disease. Not long ago a speaker attributed the lowered hospital death rate entirely to improved hospital conditions, ignoring the concurrent increase in medical knowledge and the influence of the present practice of admitting to hospitals patients with comparatively mild illnesses. Many scientists also question the value of retrospective investigations—that is, studies which go back and review the circumstances which preceded an abnormal case—because of the difficulty of obtaining histories of comparable normal cases to serve as controls. Beveridge has stressed the difficulty and the importance of separating possible causative factors in an investigation: "If when the tide is falling you take out water with a twopenny pail, you and the moon can do a great deal." [9]

In all inductive reasoning there is a point—sometimes termed "the inductive leap"—at which one must leap from the concrete to the abstract, from the accumulated data to the general statement. The scientific writer is mindful that although inductive reasoning leads only to probabilities, there is a wide range in the degree of probability. He learns to take the "inductive leap" with caution.

IV. DEDUCTIVE REASONING

Once a general principle has been accepted, it may be employed in the interpretation of new facts through the use of *deductive reasoning.* Unlike inductive reasoning which begins with the assembling of facts and generalizes from these facts, deductive reasoning begins with the statement of a principle and proceeds to apply it to a particular instance.

A. Meaning of Deductive Reasoning

Deductive thought processes can be demonstrated by expressing them in the form of a syllogism, or logical scheme of a formal argument. The *syllogism,* the theory of which was first worked out by

[9] W. I. B. Beveridge, *The Art of Scientific Investigation,* London, William Heinemann, Ltd., 1951, p. 20.

Aristotle, consists of three parts: the major premise, which states a general principle, the minor premise, which states a particular instance, and the conclusion. This may be illustrated by a classic example:

All men are mortal. (major premise)
Socrates is a man. (minor premise)
Therefore Socrates is mortal. (conclusion)

Usually people reasoning deductively do not stop to reduce their thought processes to syllogistic form. However, people are constantly drawing deductive inferences. For example, a new family moves into the neighborhood. The neighbors observe that the family car has a California license and infer that its owners came from California. Expressed as a syllogism, this reasoning would go:

Holders of California car licenses are residents of California.
This family is the holder of a California car license.
Therefore the members of this family are (or have recently been) residents of California.

Deductive reasoning is employed in applied science to relate scientific principles to particular cases. This is a simple example:

Sugar is soluble in water.
This spot is sugar.
Therefore this spot is soluble in water.

Probabilities may be expressed syllogistically if the qualification of the premise is preserved in the conclusion; for example:

Cases of illness A are usually helped by drug B.
This is a case of illness A.
Therefore it will probably be helped by drug B.

Often in less formal reasoning the major premise, particularly if generally accepted, is left unexpressed. For instance, the statement "He failed because he did not study" implies the major premise that students who do not study will fail. An argument in which one of the premises is not expressed is called an enthymeme (in the mind).

B. Fallacies in Deductive Reasoning

Stating reasoning in syllogistic form shows the grounds on which conclusions rest and helps to bring to light latent fallacies in deductive reasoning. Logicians have held, however, that a complete classification of fallacies is impossible because of the infinite possibilities of error. Nor is it possible to distinguish perfectly between the fallacies of inductive and deductive reasoning, since certain fallacies are common to both. The careless use of terms, for example, makes invalid any reasoning which depends upon the accuracy of those terms. Nevertheless, many fallacies in deductive reasoning are sufficiently common to be classified.

One group of fallacies involves treating as facts propositions which have yet to be established. This fallacy of *presumption* is evident in titles which imply in advance the validity of the author's conclusions—for example: The Dangers of . . . ; The Cumulative Nature of . . . ; The Best Plan for. . . . Again, the presumption may be implied in the words in which the argument is expressed. For instance, the statement "This nonflammable material should be used" implies that the material is nonflammable though its nonflammability may not have been demonstrated.

The terms *begging the question* and *arguing in a circle* are applied to fallacies which assume the conclusion in the major premise and then proceed in a superficially rational manner to arrive at the conclusion by means of the premise. An example is the argument that it is to the best interest of a country to be governed by a small group because then the small group can use its power for the good of all the people. A related presumption may take the form of a question such as, "When will you make a new will?" implying that a new will is to be made; or of a dependent clause, "When you sign this paper, be sure to have it notarized," implying that the paper will be signed.

A fallacy known as the *false dilemma* involves the mishandling of premises by presenting only two choices when more than two are possible. An advocate of a certain site for a power plant, for example, may mention only two possible sites—the one he favors and one obviously undesirable, ignoring the advantages of a third possibility.

Another group of fallacies is particularly concerned not with the

truth of the premises but with the correctness of their relation to the conclusion. The term *non sequitur* (it does not follow), sometimes used to apply to fallacies in general, denotes specifically fallacies in which the premises, though they may be true, are irrelevant to the conclusion or inadequate to prove it. For example, evidence that a suggested policy will have advantages is not adequate to prove that it should be adopted. Nor is evidence that it will have disadvantages sufficient to prove that it should not be adopted. The point at issue is whether the advantages outweigh the disadvantages sufficiently to justify adoption of the policy. Likewise it is not adequate to show that a situation is bad to prove that a given remedy will better it. Nor does showing that a situation could be worse sufficiently demonstrate that it could not be improved.

A gross example of a *non sequitur* in which the conclusion does not follow from the premise is this statement from a student theme: "The damage sustained by the two Japanese cities of Hiroshima and Nagasaki when the atomic bombs were exploded over them is common knowledge. Today there is hardly anyone who doubts the power of atomic energy; therefore, the purpose of this paper is to relate how research in the field of atomic energy is being used in peacetime industry." Macaulay cites a notable example of a *non sequitur* in which the premises are irrelevant to the conclusion. He objected that the defenders of Charles I were basing the issue of his competence as a ruler, not on his conduct as king, but on his conduct as a private person.

> The advocates of Charles, like the advocates of other malefactors against whom overwhelming evidence is produced, generally decline all controversy about the facts, and content themselves with calling testimony to character. He had so many private virtues! And had James the Second no private virtues? Was Oliver Cromwell, his bitterest enemies themselves being judges, destitute of private virtues? And what, after all, are the virtues ascribed to Charles? A religious zeal, not more sincere than that of his son, and fully as weak and narrow-minded, and a few of the ordinary household decencies which half the tombstones in England claim for those who lie beneath them. A good father! A good husband! Ample apologies indeed for fifteen years of persecution, tyranny, and falsehood!
>
> We charge him with having broken his coronation oath; and we are told that he kept his marriage vow! We accuse him of having given up his people to the merciless inflictions of the most hot-headed and

> hard-hearted of prelates; and the defence is, that he took his little son on his knee and kissed him! We censure him for having violated the articles of the Petition of Right, after having, for good and valuable consideration, promised to observe them; and we are informed that he was accustomed to hear prayers at six o'clock in the morning! It is to such considerations as these, together with his Vandyke dress, his handsome face, and his peaked beard, that he owes, we verily believe, most of his popularity with the present generation.[10]

Weak arguments are frequently introduced by implication since their illogicality is evident if they are fully expressed. For example, long scientific terms may be used in advertising a product to increase its appeal to the public. Yet no one would attach validity to the following argument: this product contains ingredients with long chemical names; therefore it will serve the designated purpose.

Fallacies comprising one important group result from the mishandling of the *middle term*—that is, the term which appears in both premises and upon which their relationship to the conclusion depends. In one such fallacy the difficulty is a shift in the meaning of the middle term between the major and the minor premise.

All people should be *liberals.*
The *Liberals* are in favor of this measure.
Therefore all people should be in favor of this measure.

In this example the word *liberals*—the middle term—is used in the major premise to denote people of open mind, in the minor premise to denote members of the Liberal Party.

Difficulties also arise from failure to comprehend fully the significance of the statements in the major and minor premise with reference to the middle term. Such misunderstanding may lead to such a faulty reasoning as this:

Soda is a white powder.
This unknown substance is a white powder.
Therefore this unknown substance is soda.

Here the reasoning has proceeded as if the word *is* in the premises meant *equals,* whereas it means in each case only that the subject

[10] Thomas Babington Macaulay, *Critical and Historical Essays,* New York, Frederick A. Stokes & Brother, 1888, Vol. I, pp. 36-37.

belongs to the larger class of white powders. Nothing can be inferred about resemblances or relationships between soda and the unknown except that both are white powders.

It is always easier to detect other people's errors than one's own. Nevertheless, if an awareness of the most common fallacies in logic is to be of utmost benefit to the scientific writer, he must learn to apply it to his own reasoning as well.

V. INTERPRETATION OF STATISTICS

Much of the material which the writer of scientific papers and reports has occasion to interpret is statistical data; consequently, it is desirable for everyone engaged in research to have some training in statistical method. As one statistician has pointed out, a more extended knowledge of scientific methods of collecting, analyzing, and interpreting data would do much to reduce the general confusion about the place and the validity of statistics. "The fact that expert statisticians well-versed in these methods can and do come out with sound conclusions from a given set of data which differ very little from one statistician to another is evidence that there are no real grounds for the naïve claim that statistics can prove anything." [11]

A. The Statistical Unit

The writer who is collecting or handling statistics should keep constantly in mind the importance of the *statistical unit.* The compilation of statistics involves counting or enumeration, and the unit is the thing counted. If statistics are to be meaningful, the unit to be counted must be precisely determined before the statistics are collected. In the enumeration of individuals of a certain age, for example, it must be remembered that age to the nearest birthday is not the same thing as age in years. In comparing statistics collected at different times or in different places, it is essential that the statistical units represented be the same in actuality and not merely in name. It is well known that a grade of A in an educational institution of high standards does not represent the same value as an A in an institution of low standards. Comparative studies of the in-

[11] S. S. Wilks, *Elementary Statistical Analysis*, Princeton, Princeton University Press, 1949, p. 1.

cidence of diseases are complicated by the fact that accuracy in disease detection and reporting varies. Thus a health agency of high reporting standards may list more cases of measles in the month of February than an agency of low reporting standards lists, though the actual number of cases occurring in the two areas was about the same.

Even in relatively simple situations it is not always easy to arrive at an accurate definition of the unit to be counted, as the following account shows.

> Any count of objects presupposes a definition whereby the objects to be counted may be positively distinguished from other objects which are not to be included in the count. It would seem at first thought that, aside from a possible reminder that infants and children were to be counted, as well as adults, little in the way of a formal definition of a "person" would be required as a basis for counting the inhabitants of a given state or city.
>
> But the census must count persons who belong in or to a given geographic area on a given date. There's the rub. The census of the United States cannot be taken instantaneously, nor even within the space of a single day. The period of enumeration spreads out over two, three, or four weeks, during which time persons come and go, are born, and die, in appreciable numbers.
>
> Further, there must be some criterion by which to settle the question as to who belongs in a given area which is being enumerated. In the English census a person is counted as a part of the population of the place where he is found at midnight of the census date, giving what has been termed the *de facto* population. In the United States a person is counted as a part of the population of the area within which he has his "usual place of abode," giving the *de jure* population. In the early days, when most persons were to be found for 365 days in the year at or near their "usual place of abode," the problem of counting the population was far simpler than it is now and the American census plan presented few of its present difficulties. With the increase of travel, the loose ties which bind people to their living places, and the facility with which whole families now move from one locality to another, following seasonal occupations or actuated by other motives, it seems likely that eventually the census of the United States also will have to be taken on the *de facto* basis, counting the people where they are found, even though the results have to be tabulated in such fashion as to assign each person to that area in which he has his customary residence (or perhaps his legal residence). . . .
>
> There are, therefore, three different concepts under which a geo-

graphic location might be assigned to a person for census purposes; namely, (1) where the person is found on the census date (or on the date of actual enumeration); (2) where his usual home or place of residence is located; and (3) where he has his legal or voting residence. Of these three the English census, as already noted, chooses the first. The census of the United States is now taken in accordance with the second, and conceivably some future census, seeking a strictly logical basis for apportionment of representation, may choose the third.[12]

B. Adequacy in the Treatment of Statistics

One function of statistics is to give a composite picture of a group. There is a tendency when statistics are used for this purpose to rely unduly on the *average*, or *arithmetical mean.* This, of course, is a figure obtained by totaling the numerical values of all the items in a group and dividing by the number of items. It has no validity in cases where there is no meeting ground between extremes. For instance, the *average* income would be nonexistent in a region where part of the population was wealthy and the remainder poverty stricken. The *average* daily rainfall might never occur in a locality which had a wet season and a dry season. Even a single extreme instance will affect the average so that the group as a whole appears higher or lower than it actually is. It is desirable to know also the *mode*, the value which occurs most frequently, and the *median*, or the middle value. In the following series of figures representing, for example, breakage fees—$13, $8, $7, $6, $6,—the *mode* is $6, the *median* $7, and the *average* $8. A graph or curve can show the entire distribution of a series. (See Chapter 15.)

An incomplete statistical picture may also result if percentages alone or total figures alone are given. A total of a hundred petition signers may be impressive if it is not known that the figure represents only 10 per cent of those requested to sign. The statement that 75 per cent of a club's members favored a certain action loses its significance if it is disclosed that the club has only eight members. Figures indicating correlation, that is, the degree of positive or negative relationship between two sets of values, may be misinterpreted by those not familiar with statistical methods for computing correlations. (See Appendix A, p. 407.)

[12] Leon E. Truesdell in *Methods in Social Science*, Chicago, The University of Chicago Press, 1931, pp. 199-201.

It should always be remembered that statistics deal with groups. Statistics may predict accurately what will happen to the group without predicting what will happen to any one individual. Those who work with individuals, as do doctors, lawyers, teachers, and social workers, must always be prepared for the possibility that any one individual may be the exception. Social scientists warn against interpreting any individual in terms of a *stereotype*, that is, a generalized picture of the group. Even when such a composite picture is based on complete and accurate evidence, a given individual may differ markedly from it. A stereotype based on incomplete, prejudiced, or outdated evidence, such as the cartoon caricature of the gum-chewing stenographer or the cranky schoolteacher, may be altogether unjust.

C. The Misuse of Statistics

Although statistical evidence is valid when properly used, its intricacy and impressive character make it particularly liable to misrepresentation by the self-interested and to misunderstanding by the unsophisticated. The scientific writer has a special obligation to handle statistics equitably insofar as he employs them.

Many people are impressed by statistics simply because they sound substantial and scientific. Hence statistics may be introduced to make a subjective study seem objective or to buttress a weak cause. If the statistics are irrelevant to the point at issue, this practice is, of course, a variant of the *non sequitur* fallacy. Even if related to the issue, partial statistics may be misleading. The special pleader may select statistical evidence from the place or the time most favorable to his cause. Even out-of-date statistics may impress the particularly unwary. In estimating economies, employment, number of new installations, or of accidents, for instance, overlapping categories may be combined to give an inaccurately large total.

Small errors in collecting statistics, if they all tend in the same direction, may rise to a large aggregate through processes of addition and multiplication. Stating in decimals, weights or measurements which were obtained in large fractions may give a false impression of accuracy. A British statistician has cited an instance of such misleading exactness.

> In a reply to a parliamentary question . . . , the approximate number of Moslems in the Empire was given as follows:

India	92,000,000
Dominions	161,750
Colonies	13,325,000
Total	105,486,750

The first figure is rounded to the nearest million. It is not only a waste of time to show the last six digits in the sum; it is positively misleading. The sum should be given as 105 millions approximately.[13]

VI. A REASONED ATTITUDE

From the foregoing discussion of principles it is evident that there is no easy way to accurate interpretation. The interpreter must be constantly aware of man's tendency to rationalize; in the words of James Harvey Robinson, to engage "in finding arguments for going on believing as we already do." The interpreter must be aware also of the dangers of oversimplification in its many forms—of seeking a scapegoat or a panacea, of accepting plausible explanations of cause and effect, and of reducing complex problems to simple terms.

Yet the interpreter must not become so engrossed by the exceptions and the doubtful cases that he loses perspective in viewing the whole. An experienced Committee on Research has summed up the qualities to be desired in the interpreter: "(1) a critical attitude toward the quantity and quality of evidence accumulated; (2) logical reasoning from this evidence; (3) maintenance of perspective concerning the subject as a whole; and (4) the use of good judgment in fitting the recommendations to the given situation." [14] Only constant regard for these injunctions will enable the writer to arrive at interpretations that will bring out the potential significance of his findings.

STUDY SUGGESTIONS

1. Identify the fallacies represented or referred to in the following passages: (a) Many patients recovered who were treated by the old practice of blood-letting. Therefore the treatment must have had value. (b) This appliance has developed a leak and is not usable. Therefore

[13] R. G. D. Allen, *Statistics for Economists*, London, Hutchinson & Company, Ltd., 1949, p. 73.

[14] By permission from *Manual on Research and Reports*, by the Committee on Research of the Amos Tuck School of Administration and Finance, Dartmouth College, 1937, p. 49. McGraw-Hill Book Company, Inc.

it should be replaced by a new one. (c) Men of courage always make enemies. I have enemies. Therefore I am a man of courage. (d) Our city charter should not be revised, even though it is out of date, because in the course of revision some of its good features might be lost and undesirable ones introduced. (e) Every well-informed person has some knowledge of chemistry. This individual has a knowledge of chemistry. Therefore he is a well-informed person. (f) The members of a college composition class misspelled from one to ten words on a single set of themes. Present-day college students are certainly poor spellers. (g) The voter in question must be a Republican because he comes from Vermont. (h) The law proposed should not be passed, because it is class legislation. (i) People never die at flood tide. They always "go out with the ebb." (j) All acids are not poisonous. This is an acid. Therefore it is not poisonous. (k) The last graduate of a certain preparatory school to be admitted to a college in a neighboring city made a very poor college record. Therefore graduates of this high school should not be considered for admission in the future. (l) A fallacy noted by Lynn Thorndike in *The History of Magic and Experimental Science*, Vol. I, p. 21: "But to return to the supposed immunity of the Hellenes from magic; so far has this hypothesis been carried that textual critics have repeatedly rejected passages as later interpolations or even called entire treatises spurious for no other reason than that they seemed to them too superstitious for a reputable classical author."

2. What would probably be the statistical unit in statistics concerned with each of the following: coal production, wheat production, incidence of cases of diphtheria, death rate, birth rate, unemployment, traffic accidents, industrial accidents, railroad car loadings, stock values? In each of these instances how much preliminary definition would be needed to define the statistical unit accurately?
3. Why is it necessary to define the statistical unit carefully before collecting statistics? What precautions must be observed in comparing statistics collected by different agencies or at different times?
4. Show how an average value might be misleading in each of the following instances: stock market values in September 1929, the rainfall on an island in the South Pacific, a patient's temperature readings for a three-day period, bacterial count of milk over a period of a year.
5. In commenting on Varga's experiments on rabbit muscle, experiments which had been interpreted to indicate that muscle does not contract at zero degrees Centigrade, A. Szent-Györgyi observes, "It was rather shocking to find a frog swimming about in ice water after the conclusion of these experiments, and we had to decide whether the frog or Mr. Varga was wrong." Szent-Györgyi conducted similar experiments with frog muscle and found that not until -3 degrees did it

reach the condition which the rabbit muscle had reached at zero degrees. At this point, adds Szent-Györgyi, the matter no longer interests the frog "because at this temperature he is frozen anyway." (*Chemistry of Muscular Contraction*, New York, Academic Press, Inc., 1947, pp. 48-49.) What principles of scientific method and of interpretation are illustrated by this episode?

6. Charles Darwin wrote: "I had, also, during many years followed a golden rule, namely, that whenever a published fact, a new observation or thought came across me, which was opposed to my general results, to make a memorandum of it without fail and at once; for I had found by experience that such facts and thoughts were far more apt to escape from the memory than favourable ones." (*Life and Letters*, New York and London, D. Appleton and Company, 1925, Vol. 1, p. 71.) How do logicians express the principle which Darwin had discovered from his own experience?

CHAPTER 7

DIRECTING THE PAPER TO THE READER

I. Communication as a concern of the scientist
   A. Historical division between scientific and literary writing
   B. The rise of science writing
II. Reaching a variety of readers
   A. Differences between technical and nontechnical writing
   B. A preliminary analysis of periodicals
III. The process of popularization
   A. Establishing contact with the reader
      1. The reader's self-interest
      2. Human interest
      3. Interest in the concrete
      4. Curiosity and wonder
   B. Keeping material within the reader's range
      1. A central plan of intrinsic interest
      2. The use of rhetorical devices

> *Communication is the matrix in which all human activities are embedded.* JURGEN RUESCH and GREGORY BATESON, Communication, 1951.

I. COMMUNICATION AS A CONCERN OF THE SCIENTIST

The first American journal devoted entirely to science and its relation to the arts, *The American Journal of Science,* began publication in 1818. Its founder, the chemist Benjamin Silliman, on the tenth anniversary of the journal commented on the state of scientific writing in this country at that time: " . . . our savants, unless they would be, not only the exclusive admirers but the sole purchasers of their own works, must permit a little of the graceful drapery of general literature to flow around the cold statues of science." [1]

Silliman could hardly have imagined the number and variety of readers for whom the modern scientist has occasion to write. In ad-

[1] John F. Fulton and Elizabeth H. Thomson, *Benjamin Silliman, 1779-1864, Pathfinder in American Science,* New York, Henry Schuman, 1947, p. 127.

dition to his fellow specialists and scientists in related fields, there are individuals seeking expert opinion, as well as numerous agencies which sponsor research projects and control research funds. Finally there are general readers. How large a circle of readers then should the scientist attempt to reach, and how freely may he use literary adornment in order to appeal to a more diversified group?

A. Historical Division Between Scientific and Literary Writing

A conscious distinction between a scientific and a literary English prose style goes back more than three hundred years. Richard Jones [2] has shown how British scientists of the seventeenth century deliberately avoided rhetorical ornament—then so much a feature of the prevailing literary style—because they considered rhetoric unsuited to the expression of scientific truth. Not all scientific writers were successful in avoiding the metaphors they so much deplored, as is evident from the words of Joshua Childrey in the preface of *Britannia Baconia* (1660): "I have endeavour'd to tell my tale as plainly as might be, both that I might be understood of all, and that I might not disfigure the face of Truth by daubing it over with the paint of language." Nevertheless there is ample evidence to justify the conclusions that "repugnance to the prevailing style and a feeling for the need of a simpler, more direct manner of expression were a characteristic feature of the new science from its very inception" and that style was regarded as "a distinguishing mark between the experimental philosophers and those who held to the old tradition." [3]

A widely known expression of this ideal of scientific writing appears in Thomas Sprat's *History of the Royal Society* (1667). The aim of the members was as he put it:

> . . . to return back to the primitive purity, and shortness, when men delivered so many things, almost in an equal number of *words*. They have exacted from all their members a close, naked, natural way of speaking; positive expressions; clear senses; a native easiness: bringing all things as near the Mathematical plainness, as they can: and

[2] Richard F. Jones, "Science and English Prose Style in the Third Quarter of the Seventeenth Century," *Publications of the Modern Language Association*, 45:977-1009, 1930.

[3] Reprinted from *The Seventeenth Century* by Richard F. Jones with the permission of the author and of the publishers, Stanford University Press. Copyright by the board of trustees of Leland Stanford Junior University.

preferring the language of Artizans, Countrymen, and Merchants, before that, of Wits, or Scholars.

Jane Oppenheimer in quoting this passage [4] suggests that Sir Thomas Browne's failure to be admitted to the Royal Society may have been due to his metaphorical and ornate style.

This tradition of plainness and directness in scientific style has endured to the present time, but various factors have combined to create new problems in communication for the scientific writer of the twentieth century. The extension of the scientist's technical vocabulary far beyond that of "Artizans, Countrymen, and Merchants" has made it increasingly difficult to achieve plainness. Meanwhile, the social and industrial ramifications of the scientist's work have increased, the number of potential readers has grown, and the knowledge to be communicated has been extended beyond anything which could have been foreseen. As this growing need for communication between the scientist and the public became more and more apparent in the latter half of the nineteenth century, such pioneering scientists as Thomas Henry Huxley and John Tyndall undertook the task of educating the public in science. This movement has continued until the present time, and many eminent scientists now address part of their writing to the lay reader.

Writings on science have been divided into four groups: technical papers for fellow specialists, reviews and more general papers for other scientists, textbooks, and books and articles for the general reader.[5] Some of this writing is made available to the public through scientific societies which have recognized the importance of appealing to the layman as well as to their own membership. The American Association for the Advancement of Science in addition to *Science*, its newsweekly for scientists, publishes a semitechnical journal, *The Scientific Monthly*, "for scientists—and for everyone interested in the history, progress, and philosophy of science." Similarly the American Medical Association besides its *Journal* publishes *Today's Health*, formerly *Hygeia*, for the general public. However, scientists are not entirely satisfied with their efforts to reach the general reader.

[4] Jane M. Oppenheimer, "John Hunter, Sir Thomas Browne and the Experimental Method," *Bulletin of the History of Medicine*, 21:25-26, January-February, 1947, The Johns Hopkins Press.

[5] Marston Bates, *The Saturday Review*, 35(24):16, June 14, 1952.

As one scientist has observed: "We have not solved the problem of how to write about science for the non-scientist." [6]

One reason perhaps for the persistence of this problem is that scientists have frequently shrunk from communication with the public for fear of being misunderstood. Now the view is growing that scientists are more likely to be misunderstood if they do not communicate with the public. The newer attitude toward the dissemination of scientific discoveries is expressed in the program of the 1954 meeting of the American Association for the Advancement of Science.

> The necessity for the general public to be kept informed of the results of the scientific research which it supports, directly and indirectly, is quite evident. Organized science and the individual scientist must have the understanding and support of all. It is, of course, equally important that the advances of science be publicized with accuracy and clarity without sensationalism. Progress in this direction in recent years has been most gratifying thanks largely to members of the National Association of Science Writers, other accredited science reporters, managing editors of American newspapers, and program managers of radio and television stations.
>
> It is in the interest of accuracy and completeness that science writers frequently wish to discuss various research results with investigators. If you are asked to cooperate in this respect or to participate in a press conference, please do so not only for your own protection but for the benefit of science in general.[7]

B. The Rise of Science Writing

It will be noted that the authors of scientific papers referred to in the preceding quotation are in this instance not communicating with the general public directly but through *science writers* or journalists. This branch of journalism is not to be confused with scientific writing. The scientific writer is first a scientist and secondarily a writer; the science writer is primarily a professional writer. Scientific writing stems from the scientific tradition, science writing from the journalistic tradition. However, since some science writers are well trained in science and since some scientists devote part of their time to journalism, the categories do at times overlap. Scientific writing

[6] Bates, *loc. cit.*

[7] General Program, Annual Meeting of the American Association for the Advancement of Science, Berkeley, Calif., 1954, p. 63.

done strictly by and for specialists may be termed technical writing.

Like other branches of journalism, science writing was in its early days frequently lurid and sensational, and at times still is. Since the 1920's, however, the influence of such writers as the late Howard W. Blakeslee, science editor of the Associated Press from 1927 to 1952, and Waldemar Kaempffert, a former editor of the *Scientific American* and science editor of the New York *Times* since 1931, has done a great deal to raise the general level of science writing.

II. REACHING A VARIETY OF READERS

The individual who wishes to extend his own writing range must recognize two facts. First, it is not often that the same piece of writing appeals equally to technical and lay readers since the very qualities which give it popular appeal may be unpalatable to the expert. Each paper must be directed to the reader group which it is designed to reach. Second, there are easily recognized differences which distinguish technical and popular writing; in adapting material to the destined reader group, the writer can follow specific techniques.

Certain difficulties are inherent in the process of popularization. The general reader is likely to be impatient of the caution expressed by the scientist in such qualifications as "relatively," "with reasonable assurance," "although it has not been definitely proved," "in some but not in all cases," "the observations indicate," "from the present observations," and "are essentially in agreement, except. . . ." While some scientists overwork these phrases, the use of them is representative of the scientist's caution in interpreting his results. Though science writing for the layman should be accurate by nontechnical standards, it cannot go into all the possible qualifications and objections which the technical writer is obliged to consider.

While on the whole the relations between scientists and journalists are becoming more sympathetic, there are still occasions when the scientific and journalistic attitudes are widely divergent. For example, an article entitled "How to Keep from Getting False Teeth" [8] drew cautionary comment from a Council of the American Dental Association. The article opens, ". . . now they've discovered that

[8] Herb Bailey, "How to Keep from Getting False Teeth," *Better Homes and Gardens*, 29(15):32 ff., November 1951.

chlorophyll—a chemical substance found in every blade of grass . . . —may well save you the price of a set of 'store teeth,' heal your sore mouth if your newly acquired dentures give you trouble, or let you indulge your passion for onions without risking social ostracism." A preliminary report of the Council on Dental Therapeutics of the American Dental Association concludes more cautiously, "Since the Council's preliminary consideration of the available evidence gives rise to grave doubts about the remarkable statements concerning this dentifrice, the profession may be well advised to adopt a conservative attitude toward this subject until a more comprehensive examination can be completed." [9]

The importance of scientific news and the difficulties of having it reported accurately have been summed up by E. Bright Wilson, Jr.

> But scientists are, and correctly so, under tremendous moral pressure to work incessantly for the proper utilization of their work by society. This must include strenuous efforts to educate the public, not only on the facts of science, a discouragingly vast job in view of the ignorance in this field of even most college graduates, but also on the basic aims of science, its effects, and the climate necessary for its advancement. In this enterprise most scientists are inhibited by their well-grounded fear of dealing in any way with the press. Almost every scientist has at some time yielded, as a matter of duty, to requests for interviews with newspaper reporters. In spite of the most solemn promises, his reward is all too frequently a distorted and sensational article which serves no public purpose and damages his reputation. After such experiences, many scientists shun the press as the plague.
>
> Nevertheless the public should receive information about scientific advances, and some way should be worked out to give it to them. Reporters frequently promise to show their write-ups to the scientist for correction, but they do not always live up to these promises. This check also provides little protection from the headline writers, who reporters claim are out of their reach. A perfectly sound article on an anthropological expedition is of little help if headed by "Harvard Savant Discovers Savage Love Nest." Perhaps the best procedure is to work through an experienced press officer who understands the scientist's viewpoint and who also is in a position to apply some pressure on the newsmen.[10]

[9] "Chloresium Toothpaste: Preliminary Report," *The Journal of the American Dental Association*, 43:645, November 1951.

[10] By permission from *An Introduction to Scientific Research* by E. Bright Wilson, Jr., p. 9. Copyright 1952. McGraw-Hill Book Company, Inc.

Among prizes and awards recognizing distinction in science writing have been the George Westinghouse Science Writing Awards, sponsored by the Westinghouse Educational Foundation and administered by the American Association for the Advancement of Science. Rachel Carson won the 1950 Westinghouse magazine award for "The Birth of an Island" and later received the 1951 nonfiction National Book Award for *The Sea Around Us*, a best-selling account of oceanographic research in which "The Birth of an Island" forms a chapter. In accepting the latter award Miss Carson expressed her philosophy of interpreting science to the layman.

> Many people have commented with surprise on the fact that a work of science should have a large popular sale. But this notion that "science" is something that belongs in a separate compartment of its own, apart from everyday life, is one that I should like to challenge. We live in a scientific age; yet we assume that knowledge of science is the prerogative of only a small number of human beings, isolated and priestlike in their laboratories. This is not true. The materials of science are the materials of life itself. Science is part of the reality of living; it is the what, the how, and the why of everything in our experience. It is impossible to understand man without understanding his environment and the forces that have molded him physically and mentally.[11]

A. Differences Between Technical and Nontechnical Writing

Most of the differences between technical and popular writing arise from the differing demands and purposes of the two groups of readers. General readers require background information and interpretation. They often have little or no information about the subject and little prior interest in it. Technical readers, on the contrary, have been classed as "a captive audience"—readers who are obliged to read as part of their work.

> They come to the author, furthermore, with a common background of knowledge. He does not have to tell them; they know where his work fits into the scheme of things. They want him to get down to business right away, to give them all the data and a sufficiently detailed description of the experiment so they can repeat it themselves. This leaves little space or time for generalization on what the work means. In fact, such generalization especially in American scientific literature has come to be regarded as an impropriety. As the judges of the work,

[11] *The Courier-Journal*, Louisville, February 3, 1952.

the author's colleagues claim the evaluation of its significance as their prerogative; they do not want to be told what it means.[12]

Often the title alone of an article indicates the reader group it will appeal to. All of the following titles appeared under the heading "Chlorophyll" in the *Readers' Guide:* "Green Stuff," "Nature's Deodorant," "Sweeter Smell," "Chlorophyll Formation in Potato Tubers as Affected by Temperature and Time," and "Phosphorescence of Chlorophyll and Some Chlorin Derivatives." The first three titles are definitely popular in appeal and are designed to attract the reader's attention rather than to inform him about the contents of the articles. By contrast the last two titles give an accurate and specific indication of the contents of the articles and of their exact limitations. They would repel the general reader but would attract the scientist working in the same or a related field.

The opening paragraphs of an article are likewise an indication of its potential audience. The technical article follows a logical plan, stating at once the problem in which the reader may be assumed to have interest. The article for "a wider audience of scientists" states the problem in somewhat broader terms. The article for the general reader often opens with an appeal to the reader's own interests or with a touch of human interest which will attract the reader's attention. A difference is also apparent in the words and terms used, the diction becoming increasingly technical at advancing scientific levels. The three following examples, each of which deals with an application of hybridization, show a progression from a moderately popular to an extremely technical form of presentation.

In the first example hybrid corn is presented as a "man-made product" and associated with agriculture in the American Corn Belt. Thus two human motives—pride in man's achievement and economic interest in food production—are appealed to. The wording is nontechnical, and the key term *hybrid corn* is defined.

> Hybrid corn, a man-made product developed during the past 25 years, may prove to be the most far-reaching contribution in applied biology of this century. With its accompanying improvements in farming methods, it has revolutionized the agriculture of the American Corn Belt. Because of it U. S. farmers are growing more corn on

[12] Gerard Piel, "Biology for the General Reader," *A. I. B. S. Bulletin,* The American Institute of Biological Sciences, 4(3):17, July 1954.

fewer acres than ever before in this country's history. The new abundance of food brought by hybrid corn played a significant role in World War II and in the rehabilitation of Europe after the war. Now this product, spreading to Italy, to Mexico and to other countries where corn is an important crop, promises to become a factor of considerable consequence in solving the world food problem.

What is hybrid corn and how has it made possible these substantial contributions to the world's food resources?

In a broad sense all corn is hybrid, for this plant is a cross-pollinated species in which hybridization between individual plants, between varieties and between races occurs constantly. Such natural, more or less accidental hybridization has played a major role in corn's evolution under domestication. But the hybrid corn with which we shall deal here is a planned exploitation of this natural tendency on a scale far beyond that possible in Nature.[13]

Though human motives are recognized in the second example, they are appealed to less directly. The diction is more technical; the term *heterosis,* for example, is introduced with only an incidental definition.

In the year 1932 corn was planted on 113,024,000 acres of United States farm land. The total yield for that year was 2,930,352,000 bushels, an average of 25.9 bushels per acre. In the year 1946, 3,287,927,000 bushels were harvested from plantings on 90,027,000 acres, representing a per acre yield of 36.5 bushels. The difference in yield was due in greatest measure to the use of hybrid corn on a large scale. The production of 36 bushels to the acre instead of 26 represents nothing short of a revolution. The importance of the revolution extends even further than the increased yield figures indicate, for it has freed approximately 23,000,000 acres of land for the growing of other crops or for inclusion in a rotation and conservation scheme to provide a hedge against soil fertility exhaustion.

These developments suggest startling potentialities for other crops, and they may be a consideration pointing the way out of the dilemma of increasing populations and decreasingly fertile farm lands with which most of the Temperate Zone countries of the world are faced.

The superiority of hybrid corn has its basis in a little-understood phenomenon known to biologists as heterosis. After some preliminary observations, we shall consider the various hypotheses as to the nature of heterosis. Whatever may be involved, heterosis gives to hybrids a developmental vigor which makes them larger, higher-yielding, improves the quality of their products, or otherwise renders them more

[13] Paul C. Mangelsdorf, "Hybrid Corn," *Scientific American,* 185(2):39, August 1951.

desirable than their parents. The occurrence of this hybrid advantage, generally referred to as hybrid vigor, provides one of the most intriguing of biological puzzles.[14]

The concluding example is immediately recognizable as highly technical because of its diction and the assumption that the reader will be interested in the unadorned facts.

The cytogenetical problem of introgression, as exemplified in transfer of genes from wild species of Nicotiana to cultivated tobacco, *Nicotiana tabacum*, involves special features owing to the high sterility of the F_1 hybrids and to the low degree of association of chromosomes of the two species in the hybrids. Thus in the transfer of necrotic mosaic resistance from *glutinosa* to *tabacum*, the normal hybrid is almost completely sterile and the chromosomes of the two species exhibit only a low degree of association. The sterility may, however, be overcome by crossing tetraploid instead of diploid *tabacum* with diploid *glutinosa*, producing in the first instance a relatively fertile triploid hybrid having two sets of *tabacum* and a single set of *glutinosa* chromosomes.[15]

The title, the opening paragraphs, the diction—all indicate whether an article is intended for general or specialized readers. Beyond these easily recognized hallmarks, the entire cast of a popular article will be characteristic. The article will not be as concise as one intended for the technical reader, nor will it include as much technical detail. This does not mean, however, that the popular article is merely a series of generalizations with the technical data omitted. Nothing is more discouraging to the general reader than unsupported abstractions. Carefully selected facts and cases, amplified by anecdotes, illustrations, comparisons, and references to everyday situations, replace the technical presentation of data in order to bring abstract theory within the range of the reader's experience.

B. A Preliminary Analysis of Periodicals

The habit of analyzing periodicals will help the reader in evaluating what he reads (see Chapter 4) and aid the writer in shaping his material to meet the needs of different journals. Many journals

[14] W. Gordon Whaley, "The Gifts of Hybridity," *The Scientific Monthly*, 70:10, January 1950.

[15] Roy E. Clausen, "The Cytogenetics of Introgression," *Science*, 115:481, May 2, 1952.

of interest to the scientific writer are organs of scientific societies and industrial groups so that sponsorship is always a first consideration. In general, scholarly journals do not depend upon advertising as a source of income but derive their support from subscriptions, endowments, and organizations. Contributors to learned journals customarily do not receive financial compensation but are rewarded by the opportunity to exchange results and ideas with other investigators and by the recognition accorded their work.

The outline given here suggests a plan for an analysis of periodicals which the writer can follow as fully as his current needs demand. Careful examination of representative issues, including the cover, title page, and masthead, will yield most of the information desired. To make a thorough analysis of a journal, however, it will be necessary to examine selected issues covering a period of years, including anniversary issues, and to consult such sources as N. W. Ayer & Son's *Directory of Newspapers and Periodicals*, Ulrich's *Periodicals Directory*, and *World List of Scientific Periodicals.*

Outline for an Analysis of Periodicals

I. General information
    A. Name of periodical
    B. Sponsorship
    C. Editor
    D. Place and frequency of publication
    E. Circulation
    F. Sources of income
        1. Subscriptions
        2. Endowments or organized support
        3. Advertising
II. General description
    A. Appearance
    B. Range of subject matter
    C. Reader-level
    D. Professional standing
III. History
    A. Origin
    B. Development
    C. Trends in policy

IV. Editorial policy
    A. Acceptance of articles
        1. Type
        2. Length
    B. Compensation of contributors
    C. Form of articles
        1. Titles
        2. Arrangement
            a. Subheadings
            b. Paragraphing
    D. Style preferences
    E. Documentation
        1. Adequacy
        2. Form
            a. Of citations in text
            b. Of footnotes
            c. Of bibliography
    F. Illustrations
        1. Number
        2. Kinds
        3. Size
        4. Methods of preparation
        5. Captions

If the writer is not preparing the material for publication but for submission in the form of a letter or a report to an individual, a committee, or an agency, he still must make an analysis of the interests, purposes, and wishes of his readers. (See Chapters 11 and 12.) However, the preceding outline will be primarily useful to the writer who is contemplating publication either for technical or general readers.

III. THE PROCESS OF POPULARIZATION

The writer addressing the general reader will find useful two reminders of man's natural disposition. The one is, "Whether or not it be true that the proper study of mankind is man, it is certain that he finds great difficulty in studying anything else"; [16] the other, "The

[16] J. W. N. Sullivan, *Aspects of Science*, London, Richard Cobden-Sanderson, 1923, p. 67.

more the subject matter deviates from the reader's particular interests, the greater the skill that must be exercised in retaining his attention." [17] Most readers are interested first in themselves, second in other people, third in things, and only remotely in abstract theory. Thus it follows that the reader must be led to discussions of theory through his more immediate interests.

A. Establishing Contact with the Reader

Establishing contact with the reader at the beginning of an article is particularly important; if the reader's interest is lost at this point it can never be regained. The possibilities for varying the openings of articles have been analyzed in detail. One such analysis [18] lists historical approach, specific instance, startling statement, appeal to fundamental interests of the reader, short narrative passage, quotation and literary references, definition, descriptive opening, analogy, anecdote or joke, gradual narrowing, comparison or contrast, negative detail, direct statement of thesis, particulars and details, reference to specific occasion. Most of these approaches, however, are different forms of four major appeals—to the reader's own self-interest, to his natural interest in other people, to his liking for the concrete, and to fundamental human emotions, such as curiosity or wonder.

1. The Reader's Self-interest

Few writers have shown greater skill in approaching the reader directly than has Thomas Henry Huxley, who opened an address to the working men of Norwich with these words: "If a well were sunk at our feet in the midst of the city of Norwich, the diggers would very soon find themselves at work in that white substance almost too soft to be called rock, with which we are all familiar as 'chalk.' " [19] From the chalk in the working man's pocket and beneath the working man's feet, Huxley proceeded to discuss the skeletons of organisms which made up the chalk, the history of the chalk deposits, and finally the theory of evolution.

[17] George S. Fichter, "Scientists and Science Writers," *American Scientist,* 38:137, January 1950.

[18] W. George Crouch and Robert L. Zetler, *A Guide to Technical Writing,* New York, The Ronald Press Company, 1948, p. 130.

[19] Thomas Henry Huxley, *Discourses Biological and Geological,* New York, D. Appleton and Company, 1896, p. 1.

Following the same principle, the author of an introductory history of anatomy echoes in his opening paragraph the anatomy student's inmost thoughts:

> The day when the medical student enters the dissecting room is the time of dedication to his profession; for then he puts his hand to a task which other men dread, and joins the company of those who have laid aside the deepest fears and prejudices of mankind, to seek in the dead bodies of their fellows some increase of knowledge wherewith to fight the ignorance and disease that laid them low. As he undertakes his share of this work, the student of anatomy engages in one of the oldest of the sciences. He is following a tradition of twenty-five centuries; and if he is sensitive to such influences, the burden of his work will be lightened and his effort will be quickened by a sense of pride that he is one of that profession whose history is an endless record of hard-won progress from darkness toward the light. Whether we feel it thus keenly or not, however, the influence of the past inevitably guides our hands as we work, for not only in the ancient seats of the science of anatomy, but in the newest schools of America, the methods we use, the names we learn, the present trends of our investigation have been determined by our predecessors; unless we understand them we can scarcely understand our own tasks.[20]

2. *Human Interest*

The reader's interest in other people is secondary only to his interest in himself. Consequently, the anecdote, biographical allusion, case history, and other references to people are favorite openings for articles designed for popular appeal. The following example opens with a case history (see Chapter 13).

> A number of years ago a West Indian Negro youth who was enrolled in an Illinois professional school came to a Chicago hospital complaining of fever, a cough, dizziness and a headache. He showed the scars of recent ulcers on his ankles. The attending physician, James B. Herrick, put the patient through a comprehensive examination and reviewed his history exhaustively, but was not able to identify the illness.
>
> He observed a peculiarity in the blood, however, and described it as follows: "The shape of the red cells was very irregular, and what especially attracted attention was the large number of thin, elongated, sickle-shaped and crescent-shaped forms."
>
> The odd shapes were found repeatedly in blood taken from the patient. Herrick was unable to find such cells in other persons whose

[20] George W. Corner, *Anatomy*, New York, Paul B. Hoeber, Inc., 1930, pp. 1-2.

blood he examined. He concluded: "The question of diagnosis must remain an open one unless reports of other similar cases with the same peculiar blood-picture shall clear up this feature."

That was in 1910. Herrick recorded the strange and striking phenomenon he had observed in the *Archives of Internal Medicine.* The following year a Virginia physician reported a similar case. And four years later a mulatto woman came to the Washington University Hospital in St. Louis for treatment of a leg ulcer, and again the blood showed the presence of numerous sickle cells. These three cases put doctors on the alert to watch for the abnormal shapes in blood. It soon appeared that the condition was hereditary and occurred almost exclusively in Negroes.[21]

3. *Interest in the Concrete*

Many readers who are disinclined to accept abstract ideas can be appealed to through concrete images or illustrations. In the following example a concrete description of carved panels introduces Albert Einstein to the general reader, favorably disposing him to the subsequent discussion of the abstractions in Einstein's theory of relativity.

> Carved in the white walls of the Riverside Church in New York, the figures of six hundred great men of the ages—saints, philosophers, kings—stand in limestone immortality, surveying space and time with blank imperishable eyes. One panel enshrines the geniuses of science, fourteen of them, spanning the centuries from Hippocrates, who died around 370 B.C., to Albert Einstein, who was sixty-nine years old this March. It is noteworthy that Einstein is the only living man in this whole sculptured gallery of the illustrious dead.[22]

4. *Curiosity and Wonder*

The very nature of scientific writing precludes emphasis on the emotions. However, there are among the fundamental human drives a few, such as curiosity and a feeling for order and harmony, to which the scientist may on occasion legitimately appeal. The range permitted the science writer is somewhat wider. He too, however, has been well advised to address himself to "the highest interest" of his readers rather than to contribute "to further distortion of the

[21] George W. Gray, "Sickle-Cell Anemia," *Scientific American,* 185(2):56, August 1951.

[22] Lincoln Barnett, *The Universe and Dr. Einstein,* New York, William Sloane Associates, 1948.

popular idea of science as the modern 'House of Magic' and the miscasting of the scientist as the shaman and bringer forth of wonders." [23]

The following illustration of legitimate projection of feeling is taken from an article based on material presented in one of the National Lectureships of the Society of the Sigma Xi, whose aim is the encouragement of original investigation in pure and applied science. The author undertakes to depict for the general public the "thrill" which the scientist finds in the pursuit of the unknown.

> One of the most intriguing things about research work is the totally unexpected places it may lead. The casual passer-by does not sense this. When he glances into a laboratory he sees only a man oblivious of his surroundings, huddled over a bottle-littered table or peering intently down the tube of a microscope. As he goes on his way, if he thinks again of the scientist, he probably envisages him as having thick-lensed glasses and whiskers, a shambling walk, and an impervious cloak of absent-mindedness. The visitor does not see the cherished visions, nor appreciate the possible intangible rewards of the long hours of critical observation and experimentation. He does not realize the thrill that comes to the scientist when he observes something never before seen, or finds by his experimenting the explanation of a phenomenon often seen but never understood. But the visions are there, nevertheless, for it is the dream of every investigator that some day he may feel the exaltation of unearthing the unknown. Few are destined to realize such dreams, but the dreams are always a lodestar—a hope that never dies. And whether or not any one of us is fortunate enough to explore to the end the particular paths that lead toward great accomplishment, the joy of starting along an unknown trail and following where it leads belongs to us all.[24]

The author of the next selection has set forth clearly in a few sentences the scope and purpose of his article. At the same time by personifying the quantum theory and using the words *history*, *province*, and *empire*, he has cast over the brief account something of the glamour which surrounds the course of empire.

> This is the history of a physical theory which began in 1900 by taking over a small province of physics and now has extended its empire over almost the whole of the sciences of physics and chemistry. More

[23] Piel, *loc. cit.*

[24] Bradley M. Patten, "The First Heart Beats and the Beginning of the Embryonic Circulation," *American Scientist*, 39:225, April 1951.

> precisely, it is half of the history, for it carries the story only to 1923, which happens to be about as far along the road as the non-physicist can travel easily. The story is that of the quantum theory, and this account will relate the main events in its early history.[25]

In making contact with the reader in the opening paragraphs of an article the writer should observe these precautions: the introductory material should not be so long as to delay unduly the progress of the article, the necessity for interesting the reader should not be made an excuse for the use of irrelevant anecdote or statements, and the opening paragraphs should be linked smoothly with the rest of the article.

B. Keeping Material Within the Reader's Range

Though capturing the reader's interest at the beginning is essential, this alone does not insure the success of an article. To maintain this interest the writing must remain within the range of the reader's mind and imagination. Yet the writer must avoid a tone of either writing down to his reader or sermonizing, keeping in mind the sound advice never to overestimate the reader's knowledge and never to underestimate his intelligence. Lancelot Hogben has ascribed the success of some of the great Victorians in popularizing science to their "conviction that they could *instruct* their audiences . . . their firm faith in the educability of mankind." [26] In contrast, a reviewer has censured a present-day writer for condescending to her readers.

> The author's technique is to describe the aims of the investigation, its methods, its results and their interpretations, through the device of relating her own personal and professional experiences while carrying out the tests. The text is extensively written in the first person, which in itself might be no defect. But it degrades itself in content, style, and even grammar ("If I could not get the subjects the study was a bust"; "I showed the blot to Chico, our poodle, who is the only other person anywhere near. He was very haughty about the whole thing and a little insulted") in an apparent attempt to bring the material down to the level of the lay reader. The more technical portions of the text, which have escaped transposition to colloquialism, prove to be the most readable, since they follow the first of the cardinal rules for

[25] Karl K. Darrow, "The Quantum Theory," *Scientific American,* 186(3):47, March 1952.

[26] Lancelot Hogben, *Science for the Citizen,* New York, Alfred A. Knopf, 1938, p. *vii.*

successful popular exposition, that is, they respect rather than belittle the intelligence of the reader. Dr. Roe is to be commended for her decision to describe psychological research in subjective terms, but it is a pity, particularly in view of the great inherent interest of the material presented, that she has misjudged the key in which to compose her theme.[27]

1. A Central Plan of Intrinsic Interest

The plan or scheme of organization adopted for an article is important in keeping the interest of the reader. Whether basically narrative or expository, the plan should be simple enough for the reader to grasp and follow readily. Newspaper science feature stories in which space does not permit much introductory material often rely largely on simplicity of plan and the news value of the subject to hold the reader's interest. Other sources of intrinsic appeal are the elements of drama and conflict which are inherent in many subjects.

Those who sense the elements of drama in their subjects frequently do effective popular writing. The author of a popular treatment of archaeology attributes this quality to Paul de Kruif:

> De Kruif found that even the most highly involved scientific problems can be quite simply and understandably presented if their working out is described as a dramatic process. That means, in effect, leading the reader by the hand along the same road that the scientists themselves have traversed from the moment truth was first glimpsed until the goal was gained. De Kruif found that an account of the detours, crossways, and blind alleys that had confused the scientists—because of their mortal fallibility, because human intelligence failed at times to measure up to the task, because they were victimized by disturbing accidents and obstructive outside influences—could achieve a dynamic and dramatic quality capable of evoking an uncanny tension in the reader. It was in this spirit that the famous *Microbe Hunters* evolved.[28]

In his own work Ceram highlights personality and makes full use of suspense, as in his account of the Carnarvon-Carter excavation of the tomb of Tutankhamen. (See Appendix A, p. 409.) This account is largely narrative with suspense arising from the question as to what would be uncovered as the excavations proceeded. The writer

[27] Jane Oppenheimer, Review of *The Making of a Scientist* by Anne Roe, *American Scientist*, 42:144-45, January 1954.

[28] Reprinted from *Gods, Graves, and Scholars, the Story of Archaeology*, by C. W. Ceram, translated from the German by E. B. Garside, p. *vi*, by permission of Alfred A. Knopf, Inc. Copyright 1951 by Alfred A. Knopf, Inc.

need not, however, become dependent upon the narrative form since cause and effect, analysis of contributing factors, evidence and conclusion, basis for predictions, and other expository patterns may also be developed in readable fashion if clearly presented.

2. The Use of Rhetorical Devices

Even when material seems to lack dramatic possibilities, the writer may introduce human and even dramatic interest through the use of such devices as anecdote, literary allusion, analogy, and personification. As the word *rhetorical*—descending from a Greek word meaning orator—implies, these devices which we now think of as useful to the writer originated in the orator's desire to hold the attention of his audience. Probably no one of these devices has been more frequently abused than the *anecdote*. Nevertheless the well-chosen illustrative story will often put over a point more effectively than will a long explanation.

In the following example, an anecdote enlivens the abstractions of mathematics. The graphic detail helps the reader to comprehend the idea of large numbers, always particularly difficult for the layman.

> One victim of overwhelming numbers was King Shirham of India, who, according to an old legend, wanted to reward his grand vizier Sissa Ben Dahir for inventing and presenting to him the game of chess. The desires of the clever vizier seemed very modest. "Majesty," he said kneeling in front of the king, "give me a grain of wheat to put on the first square of this chessboard, and two grains to put on the second square, and four grains to put on the third, and eight grains to put on the fourth. And so, oh King, doubling the number for each succeeding square, give me enough grains to cover all 64 squares of the board."
>
> "You do not ask for much, oh my faithful servant," exclaimed the king, silently enjoying the thought that his liberal proposal of a gift to the inventor of the miraculous game would not cost him much of his treasure. "Your wish will certainly be granted." And he ordered a bag of wheat to be brought to the throne.
>
> But when the counting began, with 1 grain for the first square, 2 for the second, 4 for the third and so forth, the bag was emptied before the twentieth square was accounted for. More bags of wheat were brought before the king but the number of grains needed for each succeeding square increased so rapidly that it soon became clear that with all the crop of India the king could not fulfill his promise to

Sissa Ben. To do so would have required 18,446,744,073,709,551,615 grains!

That's not so large a number as the total number of atoms in the universe, but it is pretty big anyway. Assuming that a bushel of wheat contains about 5,000,000 grains, one would need some 4000 billion bushels to satisfy the demand of Sissa Ben. Since the world production of wheat averages about 2,000,000,000 bushels a year, the amount requested by the grand vizier was that of the world's wheat production for the period of some two thousand years!

Thus King Shirham found himself deep in debt to his vizier and had either to face the incessant flow of the latter's demands, or to cut his head off. We suspect that he chose the latter alternative.[29]

Literary allusion or reference to figures, episodes, or situations in literature is not common in the writing of scientists, even when it is directed to the general reader. The bookish tone which such allusions produce is removed from the world of natural phenomena with which the scientist works. The professional writer guards particularly against the hackneyed or irrelevant reference. Occasionally, however, a literary allusion establishes a common literary bond with the reader.

The novel *Uncle Tom's Cabin,* alluded to in the following example, is the source of one very trite allusion—Topsy's statement that she "just growed." In the passage quoted here a scientist has turned to a less familiar passage to illustrate a complex relationship between environment and personality.

Environment (including particularly the attitude of one's contemporaries) doubtless often leads certain individuals to behave *as if* one of their physical characteristics were the cause of a behavioral difference. Thus Topsy in *Uncle Tom's Cabin* refused to behave properly because she was black, saying, "Couldn't never be nothin' but a nigger, if I was ever so good. If I could be skinned, and come white, I'd try then." Topsy seems to have appreciated also the difficulty of being accepted on equal terms by the majority, even if her behavior were up to their standards. No doubt many a person in real life is similarly deterred from attempts to live up to a different cultural ideal.[30]

Writers who wish to bring unfamiliar ideas within the range of the reader's experience frequently turn to *analogy*. An analogy is a

[29] George Gamow, *One Two Three . . . Infinity: Facts and Speculations of Science,* New York, The Viking Press, 1948, pp. 7-9.

[30] William C. Boyd, *Genetics and the Races of Man,* Boston, Little, Brown and Company, 1950, p. 14.

comparison, often extended, between two unlike things which, nevertheless, have certain essential characteristics in common. Among commonplace analogies are the comparison of the earth to an orange, the heart to a pump, man to a machine. The very readiness with which people resort to analogy entails certain dangers. An analogy may lead the reader to believe that he understands an abstraction when in reality he understands only its analogical counterpart. He may, for instance, have a fair understanding of the telephone switchboard without having any real comprehension of the human brain. Too, the analogy may be extended, through intent or through ignorance, beyond its logical application. (See Chapter 6.) If these limitations are kept in mind the analogy can be effective, as when William James compared habit to an endowment fund through which we could "capitalize our acquisitions, and live at ease upon the interest of the fund," [31] or when a newspaper columnist likened the two political parties "to two big office buildings—the tenants may move out from time to time, and different persons may occupy the offices, but the two buildings remain just as sturdy." [32]

In the following selection Sir James Jeans, physicist and astronomer, uses a series of analogies to explain the twentieth-century physicist's new philosophy, first comparing the *physicist* to a traveler and *nature* to a desert. In a subsequent paragraph an analogy between the observer of nature and the viewer of a rainbow is elaborately developed.

> That time has now come. The old philosophy ceased to work at the end of the nineteenth century, and the twentieth-century physicist is hammering out a new philosophy for himself. Its essence is that he no longer sees nature as something entirely distinct from himself. Sometimes it is what he himself creates, or selects or abstracts; sometimes it is what he destroys.
>
> In certain of its aspects, which are revealed by the new theory of quanta, nature is something which is destroyed by observation. It is no longer a desert which we explore from the detached position of an aeroplane; we can only explore it by tramping over it, and we raise clouds of dust at every step. Trying to observe the inner workings of an atom is like plucking the wings off a butterfly to see how it flies, or like taking poison to discover the consequences. Each observation

[31] William James, *Psychology*, New York, Henry Holt and Company, 1923, p. 144.

[32] David Lawrence, *Evening Star*, Washington, D. C., August 5, 1952.

> destroys the bit of the universe observed, and so supplies knowledge only of a universe which has already become past history.
>
> In certain other aspects, especially its spatio-temporal aspects as revealed by the theory of relativity, nature is like a rainbow. The ancient Hebrew—the analogue of the nineteenth-century physicist—saw the rainbow as an objective structure set in the heavens for all men to behold, the token of a covenant between God and man, and as objective as the signature to a cheque. We now know that the objective rainbow is an illusion. Raindrops break sunlight up into rays of many colours, and the coloured rays which enter any man's eyes form the rainbow he sees; but as the rays which enter one man's eyes can never enter those of a second man, no two men can ever see the same rainbow. Each man's rainbow is a selection of his own eyes, a subjective selection from an objective reality which is not a rainbow at all. And it is the same with the nature which each man sees.
>
> Again, just as a man's rainbow follows him about as he moves round the country-side, so nature follows us about. At whatever speed we move, we find nature adjusting itself to our motion, so that this motion makes no difference to its laws.
>
> Yet the analogy fails in one respect. A rainbow will disclose our own motion to us by the speed with which it moves against a background of distant forests and hills, but physical science can find no such background for nature. The whole of nature appears to follow us about.
>
> Imperfect though these analogies are, they will shew that the physicist of to-day must needs have some acquaintance with ideas which used to be considered the exclusive preserve of metaphysics.[38]

An even more extended analogy was used by H. J. Muller to stress the comparative brevity of man's existence. (See Appendix A, p. 412.)

The last device to be discussed—*the personification of a type*—cannot be considered scientific although it has proved useful in factual and informative writing of a more general nature. Such a *personification* is a sort of composite picture which has all the distinguishing characteristics of the type but is individualized by name and sometimes by personal characteristics. It lacks the scientific standing of the case history (see III-A-2 of this chapter), which is an authentic account of a typical case. The public has been known to create its own personified types—G.I. Joe, for example. Again, popular approval may carry such a personification beyond the intent of the originator. The creator of Mr. Blandings, the personification

[38] Sir James Jeans, *The New Background of Science*, Cambridge, Eng., Cambridge University Press, 1933, pp. 2-3.

of the home builder, very possibly did not anticipate the sympathetic reception which greeted the Blandings and their struggles with the house, the architect, and the contractor as described in a magazine article,[34] a book,[35] and a motion picture. A somewhat related literary form is the documentary, in which a number of typical episodes and cases are combined into a unified whole to depict a place, situation, or social problem.

The following paragraphs introduce Victor Martin, the personification of the political grafter. The last sentence of the quotation makes it clear that the name Victor Martin represents a generalized portrait rather than an individual.

> Victor Martin was in grammar and high school during the confident years before 1914. His father had done well as a city contractor and Victor went on to college, taking a sort of common denominator course and specializing in nothing because he had no idea of what kind of career he wanted. But World War I, a year in the Army, a commission as second lieutenant of infantry, and a chance afterward to help organize a local post of the American Legion, bent him toward politics.
>
> What he knew about it then he had learned chiefly from observation. His father, he was well aware, had paid graft to city councilors, state representatives, and senators: had contributed to mayors' campaign funds and had delivered the votes of those who worked for him. Victor knew this was wrong. He felt he had ideals and principles. He had seen some politicians who didn't seem to work that way, and he was determined that he wouldn't.
>
> Victor's father, interested in his ambition, spoke to a state senator. Victor was appointed executive secretary to a joint recess committee investigating electric light and power rates. When the hearings ended, he could hardly recognize his report after members tore it apart, amended, rewrote, and distorted it; but as he was Mike Martin's boy, the committee praised his work elaborately and he was taken over by the Public Utilities Commission as an assistant secretary. During the next three years he became an active member of every fraternal, service, and civic organization open to him, and managed to stand before the news camera at outings, clambakes, and celebrations. So when he became a candidate for the City Council his name was fairly well known.
>
> This candidacy of his was a carefully planned move. He had thought

[34] Eric Hodgins, "Mr. Blandings Builds His Castle," *Fortune,* 33(4):138 ff., April 1946.

[35] Eric Hodgins, *Mr. Blandings Builds His Dream House,* New York, Simon and Schuster, 1946.

> it out, talked it over with his father. He got heavy assists from the political friends to whom his father had paid graft for contracts, and the fact that he was engaged to Jean Tarbi, daughter of another contractor, did not hurt in a ward with a heavy Italian vote. In a nonpartisan election he won handily.
>
> Thus Victor Martin, at the age of twenty-five, took the first step up the political spiral stairs. He was loyal, dependable, a good campaigner, a hard worker for the party; he went down the line regularly at every primary and election. And he was ambitious. Victor Martin does not, of course, exist under that name, but almost every political reporter knows a dozen or more Victor Martins; they are to be found in every rank of government.[36]

In conclusion it may be said that this chapter does not purport to answer the question posed in its opening paragraphs concerning the extent to which scientists may employ literary devices without departing from scientific attitudes. Only scientists themselves can answer this question, and it seems unlikely that they will ever come to total agreement. There is evidence in the foregoing pages, however, that scientists are thoroughly aware of the broader problems of communication and that some scientists have employed a variety of means of reaching the general reader.

A story which Sainte-Beuve once told of a surgeon in the time of Louis XIV seems applicable here. The surgeon remarked to the French Chancellor that he wished to see an impenetrable wall erected between surgery and medicine. "But," replied the Chancellor, "on which side of the wall will you place the patient?" [37] Scientists can hardly erect a wall between themselves and the rest of society, leaving man in the position of the chancellor's patient. Therefore it seems probable that efforts to reach the general public, difficult and discouraging though the task may be at times, will continue to be an important part of scientific communication.

STUDY SUGGESTIONS

1. The paper by W. C. Allee *et al.* referred to in Chapter 1 opens with these two sentences: "When individual members of vertebrate groups are marked to permit ready recognition, they have been found to pos-

[36] Joseph F. Dinneen, "The Anatomy of Graft," *Harper's Magazine,* 205:38, July 1952.

[37] C. A. Sainte-Beuve, *Causeries du Lundi,* 3rd ed., Paris, 1850, Vol. III, p. 425.

sess a surprisingly rich social life. Territory, social hierarchy and leadership are now known to extend down the vertebrate series at least through the teleost fishes." Write a paragraph giving the necessary definitions, details, and background to make these sentences, originally directed to the technical reader, meaningful to the general reader.

2. Classify the following titles as to the reader group which they probably appealed to: "Living Records of the Ice Age," "Some Observations on the Growth and Function of Heteroplastic Heart Grafts," "Nature's Undertaker," "Theory of Braids," "Rockets," "Future of Atomic Energy," "The Problem of the Spurious Letter of the Emperor Alexis to the Count of Flanders," "When Surgeons Improvise," "Plant Hormones," "In vitro Resistance of the Genus Bacteroides to Streptomycin," "The Egg and Dr. Romanoff," "The Theory of Games," "Some Problems of Human Ecology in Polar Regions," "Danger! Population Explosion Ahead," "Science Vindicates Antihistamines," "A System of Nomenclature for Isotopic Compounds," "Radiation Damage to Genetic Material."
3. Choose a scientific concept which you feel sufficiently well informed about to undertake to explain. Check your knowledge by reference reading and then devise an analogy which you think will make this concept more intelligible. Using this analogy, write an explanation of the concept for the general reader. The following terms may suggest possible topics: ion exchange, valence, ambivalence (as used in psychology), parasite, buffer solution, diffraction, tension (restrict to one field), antibody, polymer, electrolysis.
4. In the *American Scientist*, 39:136, January 1951, James E. Miller gives the following satiric account of "How Newton Discovered the Law of Gravitation." Can this selection be classified as scientific writing? Explain your answer.

"It was on this excursion into the night air of Cambridge that Newton was struck by a flash of insight which set off a chain of events culminating in his announcement of the law of gravitation to the world in 1686. The season was autumn. Many of the good citizens in the neighborhood of the modest Newton home had apple trees growing in their gardens, and the trees were laden with ripe fruit ready for the picking. Newton chanced to see a particularly succulent apple fall to the ground. His immediate reaction was typical of the human side of this great genius. He climbed over the garden wall, slipped the apple into his pocket, and climbed out again. As soon as he had passed well beyond that particular garden, he removed the apple from his pocket and began munching it. Then came inspiration. Without prelude of conscious thought or logical process of reasoning, there was suddenly formed in his brain the idea that the falling of an apple and the

motions of planets in their orbits may be governed by the same universal law. Before he had finished eating the apple and discarded the core, Newton had formulated his hypothesis of the universal law of gravitation. By then it was three minutes before midnight, so he hurried off to the meeting of the Committee to Combat Opium Eating Among Students Without Nobility.

"In the following weeks Newton's thoughts turned again and again to his hypothesis. Rare moments snatched between the adjournment of one committee and the call to order of another were filled with the formulation of plans for testing the hypothesis. Eventually, after several years during which, according to evidence revealed by diligent research, he was able to spend 63 minutes and 28 seconds on his plans, Newton realized that the proof of his hypothesis would take more spare time than might become available during the rest of his life. He had to find accurate measurements of a degree of latitude on the earth's surface, and he had to invent the calculus.

"Finally he concluded that he must find some relief from his collegiate administrative burdens. He knew that it was possible to get the King's support for a worthy research project of definite aims, provided a guarantee could be made that the project would be concluded in a definite time at a cost exactly equal to the amount stipulated when the project was undertaken. Lacking experience in these matters he adopted a commendably simple approach and wrote a short letter of 22 words to King Charles, outlining his hypothesis and pointing out its far-reaching implications if it should prove to be correct. It is not known whether the King ever saw his letter, and he may not have, being overwhelmed with problems of state and plans for pending wars. There is no doubt that the letter was forwarded, through channels, to all heads of departments, their assistants, and their assistants' assistants, who might have reason to make comments or recommendations."

5. What is the means of explanation employed in the following example: "This magnification [that of the electron microscope] can be understood better when one learns that with it a 25-cent piece would appear to have a diameter of about 1½ miles!" (Walter C. Alvarez's column, "Dr. Alvarez on Health.") From your general reading bring in examples of explanations which you consider particularly vivid and understandable. What means have been used to bring the material within the experience of the reader?
6. Use illustrations or examples to explain what is meant by one of the following: erosion, reciprocity, calcification, perfectionist, fungus, ecology.

CHAPTER 8 SCIENTIFIC STYLE

- I. Qualities of scientific style
  - A. Essentials of scientific style
    1. Clarity and precision
    2. Conciseness and directness
    3. Objectivity
  - B. Distinction in scientific style
- II. Elements of style
  - A. Sentence structure
    1. Relationship of ideas within the sentence
    2. Faulty reference of pronouns and misrelated modifiers
    3. Illogical shifts
    4. Balance and parallelism
    5. Interrogations
    6. Revision of sentences
  - B. Diction
    1. Errors and incongruities in diction
    2. Idiomatic expression
    3. Tautology
    4. Cliché
    5. Mixed metaphor
    6. Making use of the dictionary
- III. Problems in scientific style
  - A. The influx of shoptalk and jargon
  - B. Achieving readability
- IV. Analysis of the style of a scientific paper

> *Science demands great linguistic austerity and discipline, and the canons of good style in scientific writing are different from those in other kinds of literature.*
> J. H. WOODGER, Biology and Language.

I. QUALITIES OF SCIENTIFIC STYLE

In good scientific writing the style or manner of writing does not draw attention to itself but serves as unobtrusively as possible to

embody the thought. For more than three hundred years it has been recognized that the linguistic ends and needs of the scientific writer differ from those of the litterateur. (See Chapter 7.) Scientific writing belongs to what Thomas de Quincey once called "the literature of knowledge."

> There is, first, the literature of *knowledge;* and, secondly, the literature of *power.* The function of the first is—to *teach;* the function of the second is—to *move:* the first is a rudder; the second, an oar or a sail. The first speaks to the *mere* discursive understanding; the second speaks ultimately, it may happen, to the higher understanding or reason, but always *through* affections of pleasure and sympathy.[1]

The recording of scientific observations and the formulation of scientific theory demand, as J. H. Woodger has emphasized, stringent discipline in the use of language.

> . . . English is not only used for purposes of communication in the scientific sense. It is also used for the writing of poetry, for religious devotion, for political controversy and for persuading people to buy some of the products of industrial activity which they would not otherwise want. But these pursuits make demands upon language which are very different from those made by science. The requirements of science prove on investigation to be quite surprisingly meagre, and the excessive riches of a natural language like English are a source of embarrassment. They tempt us to employ linguistic devices borrowed from extra-scientific usages which can have unfortunate consequences. Metaphors, for example, with which some branches of biology abound, are often suggestive and may be harmless enough if they are recognized for what they are. But at best they are makeshifts and substitutes for genuine biological statements, and the fact that recourse is had to them is surely a sign of immaturity.[2]

Woodger in fact has gone so far as to advocate the development of specialized languages in other disciplines analogous to the language of mathematics and the formulas and equations of chemistry. Even those commentators who are less critical of "the excessive riches of a natural language like English" recognize that the use of language for scientific communication imposes rigid restrictions on the writer.

Though no attempt will be made in this chapter to review the sub-

[1] *De Quincey's Literary Criticism,* London, Henry Frowde, 1909, p. 94. Used by permission of Oxford University Press.

[2] J. H. Woodger, *Biology and Language,* Cambridge, Eng., Cambridge University Press, 1952, pp. 7-8.

ject of English style in general, the chapter will provide a discussion of the qualities essential to good scientific style and of the stylistic problems especially likely to arise in scientific writing. (For an expression of the underlying philosophy of style, see Appendix A, p. 414.)

A. Essentials of Scientific Style

A reasoned approach to the subject of style demands a distinction between the qualities of style and the elements of style. Qualities of style represent over-all impressions or characteristics and are expressed by nouns or by descriptive adjectives. Thus a style may be said to have the qualities of clarity, terseness, simplicity, or by contrast may be described as obscure, wordy, involved. These qualities result from the author's characteristic use of the elements of style: diction, phrasing, sentence length and sentence structure, and figures of speech.

1. Clarity and Precision

It is generally agreed that the qualities of greatest importance in a good scientific style are clarity, precision, conciseness, directness, and emphasis. *Clarity* and *precision* are to a great degree interdependent. *Clarity* results when the writer is successful in making his communication understandable to the reader. *Precision* represents rather the attainment of an exact correspondence between the matter to be conveyed and its verbal expression.

Lack of clarity in a piece of writing may be attributed most often to certain specific causes.

1. The writer may not have mastered his subject matter sufficiently to be in a position to state it clearly.
2. The writer, though informed on his subject matter, may not perceive fully its inner relationships. Thus he is not able to separate the important from the unimportant and to achieve a clear, logical pattern of presentation.
3. The writer who has a thorough understanding of his subject matter may be inarticulate because of a deficiency in diction and syntax. The student who complains that he "knows but can't say it" may be acknowledging an incompetence in the fundamentals of language.

4. The writer's familiarity with his subject may prevent him from realizing what points will be obscure to his readers.

Examples of confused or ambiguous statements may be particularly helpful to students who are not aware of their own lack of clarity.

Confused	*Clearer*
It is apparent that a hypothesis which narrows the question is the only answer that can be given.	It is apparent that formulating a hypothesis that can be tested by experiment is the only feasible procedure.
When a patient who has taken penicillin develops an allergic reaction, several ways of administering it are possible.	When a patient who has taken penicillin develops an allergic reaction, the difficulty may possibly be overcome by changing the form in which the drug is administered.
With all his work he brought many new facts and aspects into the open which had not been known before.	His work introduced new facts and new theories.

The scientific writer has an obligation to use words as accurately as he does numbers and symbols. Following are examples of the imprecise use of words.

Inaccurate	*More precise*
With this information before them, ornithologists have an entirely new field open to them by which bird study may be made.	Bird banding has opened up a new field of study to ornithologists.
The new factor was called the Rh factor, using the first two letters of the *rhesus* monkeys.	The new factor was called the Rh factor after the first two letters of the word *rhesus*.

2. Conciseness and Directness

Writing that is *concise*—that expresses its meaning in the fewest possible words—saves the time and energy of the reader and contributes to readability. *Directness* also serves these ends and facilitates communication through the avoidance of circumlocutions and awkward inversions and of excessively numerous "there is" and "it

is" constructions in which the appearance of the subject is delayed. In general, directness is the foe of verbiage, which impedes a simple, straightforward approach.

Wordy	*More concise*
There is an abundance of evidence in the literature which supports the view . . .	An abundance of evidence in the literature supports the view . . .
The fact that these critics ignore is that this test has been made several times in the past.	These critics ignore the fact that this test has been made several times in the past.

3. Objectivity

It is expected that the scientist's style should reflect the *objectivity* of his attitude toward the problems he investigates and toward his results. This emphasis on objectivity as a quality of scientific style implies that in subordinating subjective considerations, scientific style should be more formal and more impersonal than is prose style in general. Slang, colloquial expressions, and localisms are avoided; strict grammatical usage is observed; close is preferred to open punctuation; and a technical rather than everyday vocabulary is employed.

There is some difference of opinion as to whether impersonality in writing requires the use of the third person style in which the author refers to himself as "the writer," in preference to the first person style in which "I" or "we" is used. Some editors and advisers recommend the use of the first person, maintaining that its simplicity and directness outweigh any supposed gain in objectivity resulting from the use of the third person.[3] Among writers themselves, however, there is a tendency toward the use of the third person, and some authorities recommend or specify this practice, especially in formal communications.[4] When the third person style is used, it may be necessary to employ the phrase "the present author" or "the present

[3] See *The Wistar Institute Style Brief*, p. 7; also Joseph N. Ulman, Jr., *Technical Reporting*, New York, Henry Holt and Company, 1952, pp. 92-95.

[4] See William Giles Campbell, *Form and Style in Thesis Writing*, Boston, Houghton Mifflin Company, 1954, pp. 61-62; also W. George Crouch and Robert L. Zetler, *A Guide to Technical Writing*, New York, The Ronald Press Company, 1948, p. 129.

writer" to prevent confusion with authors quoted or referred to. Whatever the point of view adopted—whether the author is referred to as "I" or "the writer"—it should be maintained throughout the paper. In any event, if the writing is objective and impersonal in spirit, occasions for references to the author or authors will be few.

The first of the three examples given here shows the first person singular pronoun referring to a single author, the second shows the first person plural pronoun referring to coauthors, and the third illustrates the impersonal third person construction.

> The formation of Liesegang Rings is adequately explained by the theories of Ostwald and Chatterji and Dhar; an explanation of the origin of the radial lines, for which I propose to use the term *radii*, is still lacking.[5]

> In the fall of 1941 we had an opportunity to study 18 adult male and female *C. v. viridis* recently removed from a hibernating den located near Cheyenne, Wyoming.[6]

> The problem confronting the reviewer is, as usual, how to present the field in the space allowed. No apologies are offered for materials not included. . . .[7]

The passive voice is more frequently used in scientific than in general writing because it contributes to impersonality of style and because in scientific work the personal agent is often subordinated to what takes place; unfortunately, this legitimate use of the passive voice often becomes so habitual that the writer neglects to make use of the more forceful active voice even when its use is desirable.

The passive voice is justified in the two following examples since nothing would be gained by reference to the agent—the experimenter.

> Lead shielding 2 cm thick was placed so as to protect all plant parts except the short length of stem to be irradiated.[8]

[5] H. Friedeberg, "Diffusion Lines in Silver Chromate Gelatin," *Science*, 119: 651, May 7, 1954.

[6] L. E. Chadwick and Hermann Rahn, "Temperature Dependence of Rattling Frequency in the Rattlesnake, *Crotalus v. viridis*," *Science*, 119:442, April 2, 1954.

[7] J. S. Nicholas, "Developmental Physiology," *Annual Review of Physiology*, 10:43, 1948.

[8] Eric Christensen, "Root Production in Plants Following Localized Stem Irradiation," *Science*, 119:127, January 22, 1954.

As the experiment progressed, additional water was added to equal the amount lost from evaporation.[9]

Recasting in the active voice is an improvement in the next example, which is more concise and direct in the revised form.

Original	*Revision*
This procedure may be justified in the interest of economy.	Economy may justify this procedure.

Scientists differ about the extent to which figurative language may be employed in scientific writing. Owsei Temkin, in contributing to the University of Wisconsin centennial symposium "Science and Civilization," points out that writers of the past helped by the use of metaphors to shape the concepts of biological science.[10] Similarly a contributor to a symposium on "Form in Nature and Art" writes of "the engineering problems which living organisms have had to face" and refers to the biochemist Frederick Gowland Hopkins as "possessed of a particularly penetrating gift of imagination, which enabled him to visualize the protoplasm of the cell as a kind of chemical factory, where a large number of reactions were able to proceed in close contiguity without becoming disorganised." [11]

Another point of view, represented by the comment of J. H. Woodger, quoted earlier in this chapter, is that language can become completely serviceable to science only as it draws away from the use of metaphor. It may be said at least that adherence to strict standards of scientific writing demands limitation in the use of figures of speech, particularly those which reflect emotion. The statement "nature abhors a vacuum," for example, is no longer considered genuinely scientific, nor is it a mark of scientific sophistication to refer subjectively or emotionally to experiments or results. In such a statement as "Unfortunately it was impossible to collate the data at that time" the word *unfortunately* should be omitted.

[9] W. H. Preston, Jr., John W. Mitchell, and Wilkins Reeve, "Movement of Alpha-Methoxyphenylacetic Acid from One Plant to Another Through Their Root Systems," *Science*, 119:437, April 2, 1954.

[10] Owsei Temkin, "Metaphors of Human Biology," *Science and Civilization*, Madison, University of Wisconsin Press, 1949, pp. 169-94.

[11] Joseph Needham, "Biochemical Aspects of Form and Growth," *Aspects of Form*, New York, Farrar, Straus & Young, Inc., 1951, pp. 77 and 83.

These essentials of good scientific style—clarity, precision, conciseness, directness, and objectivity—are all stressed in the following editorial directive concerning style.

> The style of presentation should be of the simplest, most direct and thoroughly objective type, since the purpose of the writing is to inform and not to entertain. Brief, clear and concise sentence structure is, perhaps, the most important feature of such a style. If to this is added a careful analytical outline, as a guide to the arrangement of the material, the paper should clearly convey the author's observations and conclusions. Circumlocutions, excessive qualification and irrelevant detail confuse the issue. . . . Words should be accurately adjusted to the shade of meaning desired. If a thing is actually observable it should be so stated and not be mentioned in conditional terms. Repetition is undesirable in written presentation. Final steps and conclusions, not the author's developmental progress in understanding and appreciation, are what interest qualified readers.[12]

B. Distinction in Scientific Style

It is possible for a piece of scientific writing to have the essential qualities of style and still to be flat and dull. The qualities of smoothness, rhythm, emphasis, and even epigrammatic expression, which lift writing above mediocrity are, however, difficult to acquire by conscious effort. Writers who have commented on the subject agree that smoothness and rhythm are best developed by wide reading among the great English stylists. The writer who couples his reading with extensive practice in writing in an effort to improve his own style may find useful guidance in H. W. Fowler's definition of rhythm. "A sentence or a passage is rhythmical if, when said aloud, it falls naturally into groups of words each well fitted by its length and intonation for its place in the whole and its relation to its neighbors . . . For, while rhythm does not mean counting syllables and measuring accent-intervals, it does mean so arranging the parts of your whole that each shall enhance, or at the least not detract from, the general effect upon the ear; and what is that but seeing to it that your sentences sound right?" [13]

[12] *The Wistar Institute Style Brief*, Philadelphia, The Wistar Institute Press, 1934, p. 7.

[13] H. W. Fowler, *A Dictionary of Modern English Usage*, Oxford, Oxford at the Clarendon Press, 1927, p. 504.

Like smoothness and rhythm, emphasis is attained partly by unconscious imitation. The writer may, however, rely on the principle that the beginning and end of the sentence are the strongest positions. Hence emphasis will be gained if important elements are placed in those positions and not relegated to the less conspicuous middle position. A good sense of sentence rhythm also contributes to emphasis. Since the cadence of a passage will in part determine where the verbal emphasis falls, the skilled writer can use this natural stress to reinforce the important elements in his thought.

In the following example, italics have been added to indicate points of emphasis as they are determined by the positions of words at the ends of clauses and sentences, balance and parallelism, and sentence rhythm. The order of climax in the concluding sentence is especially noteworthy.

> No one would deny that *science* has had a great *effect* on the *religious outlook.* If I were asked to sum up this effect as briefly as possible, I should say that it was *two-fold.* In the *first* place, scientific discoveries have entirely altered our general picture of the *universe* and of *man's position* in it. And, *secondly,* the application of scientific method to the study of religion has given us a *new science,* the *science* of *comparative religion,* which has profoundly changed our general views on *religion itself.* To my mind, this *second* development is in many ways the more important of the *two,* and I shall begin by trying to explain *why.* There was a time when religions were simply divided into *two categories,* the *true* and the *false;* one *true* religion, revealed by *God,* and a mass of *false* ones, inspired by the *Devil.* Milton has given expression to this idea in his beautiful "Hymn on the Morning of Christ's Nativity." This view, unfortunately, was held by the adherents of a number of different religions—not only by *Christians,* but also by *Jews, Mohammedans* and *others.* And with the growth of intelligent tolerance, many people began to feel *doubtful* about the *truth* of such *mutually contradictory statements.* But the *rise* of the *science* of *comparative religion* made any such beliefs virtually *impossible.* After a course of reading in that subject, you might still believe that your *own* religion was the best of *all* religions; but you would have a very queer intellectual construction if you still believed that it *alone* was *good* and *true,* while all others were merely *false* and *bad.*[14]

To summarize, good scientific style conveys meaning with a maximum of directness and accuracy and a minimum of interference.

[14] Julian Huxley, in *Science and Religion: A Symposium,* New York, Charles Scribner's Sons, 1931, p. 2.

Though it is not lacking in aesthetic value, its aesthetic appeal is functional and intrinsically related to content. The scientific writer should have an understanding of simplicity as Frank Lloyd Wright once defined it—"to know what to leave out and what to put in, just where and just how." [15]

II. ELEMENTS OF STYLE

When questions arise concerning usage, sentence structure, spelling, punctuation, and capitalization, the writer may refer to a standard handbook of English composition and to a standard dictionary. Where practice differs concerning such details as capitalization and abbreviations, editorial and departmental style sheets and technical dictionaries afford guidance. Two major concerns—sentence structure and diction—are so closely associated with the logic of scientific writing that they merit discussion here.

A. Sentence Structure

Editors generally agree in their emphasis on sentence structure, ranking it, with diction and logical organization, among the aspects of composition which the writer should master.

1. Relationship of Ideas Within the Sentence

Certainly, the scientific writer who understands and appreciates the capacities of the sentence for expressing simple and complex relationships will find it a responsive medium in giving form to his observations and generalizations.

For stating an uncomplicated, unqualified observation a simple sentence is used.

> From June to September Trident's activity was marked by quiet extrusion of lava accompanied by steady, moderately vigorous steaming.[16]

The compound sentence expresses co-ordinate ideas in balance or contrast.

[15] Frank Lloyd Wright, *Modern Architecture, Being the Kahn Lectures for 1930*, Princeton Monographs in Art and Archaeology, Princeton, Princeton University Press, 1931, p. 76.

[16] Ernest H. Muller, Werner Juhle, and Henry W. Coulter, "Current Volcanic Activity in Katmai National Monument," *Science*, 119:319, March 5, 1954.

The flow is dark brown and blocky on the surface, but it continues to steam from hot viscous lava beneath.[17]

In the complex sentence dependent clauses are used to express ideas subordinate to the thought of the main clause.

In the year 1675, I discovered living creatures in rain water, which had stood but a few days in a new earthen pot, glazed blue within.[18]

Generalizations whether of fact or opinion may be expressed in simple sentences when the ideas are so completely crystallized that little or no condition or qualification is necessary.

Mercury will dissolve many metals, such as pieces of tin or gold, but not iron, nor substances like salt, sugar, or wax.[19]

Great specialization is associated with corresponding limitations in other directions.[20]

When a generalization involves a subordinate idea of consequence a complex sentence is required, as in the following axiom from Newton's Laws of Motion.

Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it.[21]

Scientific writing allows less latitude in sentence structure than does creative writing. Unconventional verbless sentences or contact clauses (independent clauses joined by a comma) are rare in scientific writing. Lapses such as those in the following examples taken from student papers require revision.

[17] *Loc. cit.*

[18] Anton van Leeuwenhoek, "Little Animals in Rain Water," *The Autobiography of Science*, New York, Doubleday Company, Inc., 1946, p. 158. Leeuwenhoek spoke and wrote only Dutch. His letters to the Royal Society, from which this excerpt is taken, were translated for publication in the Society's *Philosophical Transactions.*

[19] Julian Huxley and E. N. da C. Andrade, *Simple Science*, New York, Harper & Brothers, 1935, p. 49.

[20] Edwin Grant Conklin, *Heredity and Environment*, 5th ed., Princeton, Princeton University Press, 1923, p. 252.

[21] Sir Isaac Newton, *Mathematical Principles*, revision by Florian Cajori of Motte's translation, Berkeley, University of California Press, 1946, p. 13.

Incorrect	*Correct*
Also the fact that there are differences of opinion among members of the profession as to the meanings of terms.	Also there are differences of opinion among members of the profession as to the meanings of terms.
Although if this apparatus is operated under pressure, objectionable quantities of gas escape.	If this apparatus is operated under pressure, objectionable quantities of gas escape.
The combustion chamber was quartz and the furnace brick-lined, a silica tube cooler was used to cool the gas.	The combustion chamber was quartz and the furnace brick-lined; a silica tube cooler was used to cool the gas.
The author does not name the materials of which the burner was constructed, however, it seems that he used refractory materials such as silica.	The author does not name the materials of which the burner was constructed; however, it seems that he used refractory materials such as silica.

Failure to establish correct structural relationships between the main and subordinate ideas in a sentence results in loosely constructed compound sentences or in faulty subordination.

Faulty co-ordination	*Improved*
In February 1930 he was married, and in 1933 after making various archaeological expeditions, he wrote his treatise on the subject.	In February 1930 he was married. In 1933, after making various archaeological expeditions, he wrote his treatise on the subject.
Although the book will be of greatest value in introductory courses, it includes material from several different levels.	Although the book includes materials from several different levels, it will be of greatest value in introductory courses.

2. *Faulty Reference of Pronouns and Misrelated Modifiers*

Faulty reference of pronouns and dangling and misplaced modifiers are responsible for many of the ambiguous statements and ludicrous errors which vex the editorial reader.

Reference of Pronouns

Faulty	*Revised*
The president's statement not only strengthened the feeling of uncertainty but also suggested changes in policies that the members of the board disapproved of.	The president's statement not only strengthened the feeling of uncertainty but also suggested policy changes that the members of the board disapproved of.
The temperature readings varied several points that day which left the interpretation of the results still more obscure.	A variation of several points in the temperature readings that day left the interpretation of the results still more obscure.

Dangling Modifiers

Faulty	*Revised*
Realizing that dogmatic statements are unscientific, the following material will be presented with the understanding that it is in accord with the best research available at this time.	Realizing that dogmatic statements are unscientific, I shall present the following material with the understanding that it is in accord with the best research available at this time.
When working on a large scale, it is more practical to prevent these conditions than to attempt to cope with them.	When the work is done on a large scale, it is more practical to prevent these conditions than to attempt to cope with them.

Misplaced Modifiers

Faulty	*Revised*
A sponge was placed on the nose of the person filled with narcotics.	A sponge filled with narcotics was placed on the person's nose.
The members were requested to fill out the questionnaire enclosed in ink.	The members were requested to fill out in ink the questionnaire enclosed.

3. Illogical Shifts

While changes in thought may necessitate changes in tense, person, voice, mood, and sentence pattern, irrational shifts are never justified. Practice concerning tense, it may be noted, differs somewhat in different fields. One group of editors states, for example:

> Careful choice of tense, appropriate to the event, will make for brevity and clearness. A persistent condition observed at all times should be described in the present tense, while one which characterizes particu-

> larly the conditions of the observation or experiment should be in terms of the past tense.[22]

Another editorial preference is for adherence, in general, to the past tense.

> Writers often skip lightly from one tense to another, even in the same paragraph, and not infrequently confuse the reader. Furthermore, [William H.] Woglom emphasizes that good reason does not exist for describing experiments in the past tense and microscopic morphology in the present, though this is common practice. Perhaps safest is to keep to the past tense in all descriptive matter. . . .
>
> A related difficulty arises with regard to the expressions "he believed" and "he believes." In many instances it is impossible to determine whether the view cited is still held and therefore whether "he believes" is correct. "He believed," on the other hand, may leave the reader with the impression that the opinion has been abandoned. In the publications of this press the difficulty is avoided as a rule by changing the verb of thinking to a verb of saying, so that, for instance, "Brown considered" becomes "Brown expressed the opinion." In reviews of recent literature in which the verbs of saying are in the present tense and in papers in which an author is discussing recent work by men whose opinions he obviously knows well, "he believes" is of course permissible.[23]

The following examples show unjustified shifts in tense, person, voice, and mood with accompanying revisions.

Shift in tense	*Revised*
These effects were usually concentrated on the blood system of the animal. The count of red and white blood cells is affected greatly. The percentage of hemoglobin was also reduced.	These effects were usually concentrated on the blood stream of the animal. The count of red and white blood cells was affected. The percentage of hemoglobin was also reduced.
Shift in person	*Revised*
First, a new filing system can be introduced. Second, you can train personnel to handle the present complicated system.	First, a new filing system can be introduced. Second, personnel can be trained to handle the present complicated system.

[22] *Wistar Institute Style Brief,* p. 7.

[23] By permission from *Medical Writing,* 2nd ed., p. 15, by Morris Fishbein. Copyright 1948. McGraw-Hill Book Company, Inc.

Shift in voice
The technicians began the tests on March 15, and the results were tabulated the following day.

Revised
The technicians began the tests on March 15 and tabulated the results on the following day.

Shift in mood
The student should take meaningful notes in outline form and keep them in order. Do not cram.

Revised
The student should take meaningful notes in outline form and keep them in order. He should not cram.

A shift in sentence pattern occurs when the writer begins his sentence with one construction in mind and concludes it with another.

Confused
It was because of a natural interest that made me choose the topic of anesthesia.

As to whether a person suffering from self-pity could apply the advice intelligently and with perseverance is doubtful.

Corrected
It was because of a natural interest that I chose the topic of anesthesia.

Whether a person suffering from self-pity could apply the advice intelligently and with perseverance is doubtful.

4. Balance and Parallelism

Writers frequently begin the listing of a series of problems, purposes, effects, etc., only to break balance and parallelism by introducing grammatical inconsistency or by abandoning the series before completing it. Faulty parallelism and balance may also result from the omission of necessary words, mishandling of correlative conjunctions, and incomplete or illogical comparisons. The following examples illustrate faulty parallelism and balance and suggest ways of correcting it.

Faulty
These phenomena include change of heart-beat rate, controlled dilation of the pupil of the eye, and recall or inhibit experiences which were a part of normal waking consciousness in the past.

Revised
These phenomena include change of heart-beat rate, controlled dilation of the pupil of the eye, and the recall or inhibition of experiences which were a part of normal waking consciousness in the past.

Faulty	*Revised*
The investigator neither made a report nor a verbal statement to the committee.	The investigator made neither a report nor a verbal statement to the committee.
Your judgment is as good as some of us who are years your senior.	Your judgment is as good as that of some of us who are years your senior.

5. *Interrogations*

Interrogations are not encountered with great frequency in scientific writing. Occasions for direct questions seldom arise and the rhetorical question is a literary rather than a scientific device. At times, however, the question form may be used advantageously to present a problem or to raise a topic for discussion. Each of the three questions quoted here serves to introduce one of three successive paragraphs in the author's "Discussion." [24]

> At what point in the development of the young of *Pomacentrus* do the melanophores become active?
>
> How does the melanophore picture of the embryos and larvae of *Pomacentrus* fit into the picture given by the reports of other investigators in regard to their work on other fish embryos and larvae?
>
> What is the interpretation of these data?

6. *Revision of Sentences*

The consideration of sentences isolated from their context, like the examples in this section, serves the purpose of focusing attention on specific weaknesses with which the student must cope. The student, faced with the task of revising his manuscript sentence by sentence, may find encouraging the knowledge that Charles Darwin "did not write with ease, and was apt to invert his sentences both in writing and speaking, putting the qualifying clause before it was clear what it was to qualify. He corrected a great deal, and was eager to express himself as well as he possibly could."

[24] B. R. Coonfield, "Chromatophore Reactions of Embryos and Larvae of Pomacentrus leucostictus," *Papers from Tortugas Laboratory,* Vol. XXXII, Carnegie Institution of Washington Publication No. 517, Washington, D. C., 1940, pp. 176-77.

In commenting on these statements of Darwin's daughter, his son Francis Darwin adds:

> Perhaps the commonest corrections needed were of obscurities due to the omission of a necessary link in the reasoning, something which he had evidently omitted through familiarity with the subject. Not that there was any fault in the sequence of the thoughts, but that from familiarity with his argument he did not notice when the words failed to reproduce his thought. He also frequently put too much matter into one sentence, so that it had to be cut up into two.
>
> On the whole, I think the pains which my father took over the literary part of the work was very remarkable. He often laughed or grumbled at himself for the difficulty which he found in writing English, saying, for instance, that if a bad arrangement of a sentence was possible, he should be sure to adopt it. . . . When a sentence got hopelessly involved, he would ask himself, "now what *do* you want to say?" and his answer written down, would often disentangle the confusion.[25]

B. Diction

Probably no element in writing is more closely associated with an author's thought than are the words which he chooses to convey his meaning. Nevertheless, writing in both student papers and published work too frequently displays a weakness in diction.

1. Errors and Incongruities in Diction

Many errors in diction arise from mistaking one word for a related word: *infer* (conclude) for *imply* (suggest); *effect* (bring about) for *affect* (influence); *homogenous* (alike in structure) for *homogeneous* (alike in nature). Such confusion misled the student who wrote, "Examples were presented and conclusions *deducted*." Again, words may be incorrect in combination: "The author gave the theory of these techniques." One might "give" an *explanation* of a theory but hardly the theory itself. Similarly it is unwise to use the same word in different senses in close proximity, as in the example quoted by one editor: "After reaching Greenland the authors reached different conclusions." [26]

[25] *The Life and Letters of Charles Darwin,* edited by his son Francis Darwin, New York and London, D. Appleton and Company, 1925, Vol. I, pp. 130-31.

[26] Eugene S. McCartney, *Recurrent Maladies in Scholarly Writing,* Ann Arbor, University of Michigan Press, 1953, p. 28.

The undiscriminating writer fails to make a careful selection among such synonyms as *dull, blunt, obtuse,* or as *pay, reimburse, indemnify, recompense, compensate*—which, though similar in meaning, are by no means interchangeable. Or he may lapse into outright illogicalities: "The identical procedure was followed with the exception that. . . ." If the procedures were identical, no exception would be possible. The word *fact* is often illogically used:

> The facts he tells are few, and subsequent research has shown that they are inaccurate.[27]

> However, a number of facts remain to be established.

Such blunders are due in part to the tendency to overwork a few words instead of seeking the exact and appropriate word. On slang levels this tendency results in every object being known as a "doodad" or a "thingamajig," every person disapproved of being designated as a "pill" or a "dope," and everything approved of being described as "smooth" or "cool." Yet writers who carefully avoid all suspicion of slang may be equally injudicious in their use of such words as *thing, factor, field, interest, function,* which are often used to the point of monotony.

2. Idiomatic Expression

The idioms of a language are expressions, usually of long standing, which cannot be grammatically analyzed or logically explained. Writers who are trying hard to be technically correct sometimes avoid the use of such expressions. This extreme caution results in stiff, stilted writing—what is known as an "unidiomatic" style. Among the idioms most frequently violated are those involving prepositions. The best preventive of departures from idiom is wide reading in those English writers who are recognized masters of idiom. It is also helpful to consult handbooks and dictionaries which list idioms, usually under the key word of the phrase.

The use of idiom often makes possible the succinct phrasing of an idea. For instance, Sir James Jeans' statement "It [humanity] has before it time enough and to spare in which it may understand

[27] *Ibid.*, p. 39.

everything" would be more cumbersome if expressed less idiomatically. Examples of violations of idiom, with revisions, follow.

Unidiomatic	*Revised*
Probably no city in the United States of any age or size has not experienced the sporadic and unorganized rebuilding of sections of its central core areas.	Probably no city in the United States of any age or size has escaped the sporadic and unorganized rebuilding of sections of its central core areas.
The project was undertaken for the benefit to the public.	The project was undertaken for the benefit of the public.

3. Tautology

Tautology—the needless repetition of meanings, differently expressed—is an extreme form of wordiness. It is usually not difficult to avoid the more glaring tautological expressions such as sometimes occur in student themes: "Lincoln's fatal death," "fiction novel," "the first primary necessity," "when gases combine together." One should, however, guard also against less obvious but still objectionable tautologies such as "employ the use of" for "use," "during the daytime" for "during the day," and "recopy" for "copy."

4. Cliché

A *cliché* is a trite, overworked phrase, so called after a French word denoting a stereotype plate or cast of type. Such phrases as "last but not least," "beg to differ," "all walks of life" give the impression that the writer is willing to borrow worn-out words of others rather than exert himself to find fresh words which express his thought. The habitual use of clichés indicates that the writer has become uncritical of his own style. Like overworked slang, clichés, as Frederick A. Philbrick has pointed out, lower the tone of a composition.

> . . . such things are fatal to the creation of mood. A lawyer's argument is equally valid whether he expresses it in terse and vivid English or in hackneyed phrases that might have been taken from the balloon-enclosed conversations of the comic strip. But the mood that might win him a verdict is fatally injured by such mistakes, and just

as a vulgarism can destroy the mood produced by a sermon, so can a lawyer's eloquence be made ineffective if his diction shows too clearly that he spent a neglected youth.[28]

5. *Mixed Metaphor*

Although scientific writing requires the use of relatively few figures of speech (see Section I-A-3), no writing is entirely devoid of figurative language. The *metaphor,* or implied comparison, is the basis of many everyday expressions—"run for office," "place the blame," "pass over the objection," "table the motion." The careless mixing of metaphors, as in the following examples, offends both editors and readers.

> President Truman was an unknown quantity when he was tossed into the maelstrom of world affairs on a scale never before known to history.

> We may now have the determination to take the unpalatable but necessary steps for our survival.

> In another letter, the question of agreeing on the price was a bone of contention.

6. *Making Use of the Dictionary*

When Sir William Osler made his famous comment, "After all, there is no such literature as a Dictionary," he showed the way to a full appreciation of the dictionary as a repository of knowledge. This reference makes available a wealth of information—geographical, theological, literary, rhetorical, philosophical, historical, sociological, economic, scientific, and linguistic. In using the dictionary to solve problems of diction the student will find, in addition to the definition of a word, its pronunciation, spelling, syllabication, derivation, classification among the parts of speech, and usage level. The listing of synonyms and antonyms is helpful in making discriminating choices among words and in expressing fine shades of meaning.

[28] Frederick A. Philbrick, *Language and the Law,* 1949, p. 23. Used with the permission of The Macmillan Company.

Many representatives of professional institutions and business groups have expressed concern in recent years about the faulty spelling of some college students and graduates. (A list of words reported as misspelled in science and professional courses appears in Appendix A, p. 415.) Students who have difficulty with spelling will find it expedient to supplement the use of the dictionary with an analysis of their individual spelling problems.

III. PROBLEMS IN SCIENTIFIC STYLE

Apart from individual problems in attaining an adequate and pleasing style, there are broader problems of scientific style which have provoked wide discussion. Among such problems are the influx of shoptalk and jargon and the attainment of readability in scientific writing.

A. The Influx of Shoptalk and Jargon

Because of its factual, impersonal character, scientific writing is subject to two frequently associated forms of vulgarization—*shoptalk* and *jargon*. *Shoptalk* is the laboratory or office slang or colloquial usage characteristic of a professional or business group. Permissible, perhaps, in the oral exchange incident to the day's work, shoptalk is likely to be objectionable when transferred to writing. The abbreviating of frequently used terms such as *lab, hypo, schizo;* the piling up of nouns used as adjectives as "the *business world type* man"; the use of such questionable forms as *enthused, accessorize, phony*—these are characteristic of shoptalk and lower the tone of a piece of writing. Many companies forbid the use of shoptalk and localisms in reports because the terminology of a report must be such that the report can be circulated to other branches of a company and be understandable in years to come.

Of somewhat different origin, *jargon,* or writing which is unnecessarily pretentious, verbose, and involved, derives its name from its unintelligibility. Sir Arthur Quiller-Couch years ago identified the marks of jargon as first, the use of vague, "fuzzy," abstract nouns in preference to specific concrete ones; second, a tendency toward elaborate circumlocution.

Jargon	*Improved*
One of the major causes of inaccurate or fallacious interpretations of the results of an experiment or investigation is the absence of the experimenter's or investigator's cognizance of his basic assumptions in the area of the particular experimentation or investigation.	One of the major causes of the misinterpretation of experimental results is the experimenter's failure to understand the basic assumptions underlying his study.
We are about to enter an area of activity.	We are ready to begin.

More recently, Representative Maury Maverick coined the term *gobbledygook* to designate the excessively wordy, obscure jargon often found in official documents and exemplified by the following passage.

> The careers department, not to be confused with the placement office, has taken its position on the campus because this institution recognizes the need to obviate one contributing factor in careers maladjustment stemming from inadequacy of occupational information and sound interpretation during the undergraduate training.

B. Achieving Readability

In recent years the terms *readability* and *readability yardsticks* have become rallying points for many of those who have resisted the influence of jargon in current factual writing. This group asserts that many writers, particularly scientific writers, in an effort to be formal, have become pretentious and have deviated farther and farther from simplicity of speech. As the proponents of "readability" themselves recognize, their position is not entirely new, but is a recent development of the old conflict between the plain and the literary style.

> The history of English prose is, in fact, the history of the plain style and successive attempts to replace it by something else. All these attempts broke down in the end; the plain style is the only classic style that has survived. The pomposities and complexities of Dr. Samuel Johnson, Edward Gibbon, Edmund Burke, Walter Savage Landor, Thomas Carlyle, John Ruskin, and Walter Pater are now museum

pieces; the simplicity of John Bunyan, Samuel Pepys, John Dryden, Daniel Defoe, Jonathan Swift, and Oliver Goldsmith is still a model of good writing.[29]

The belief that readability can be measured has grown up during the past thirty years and has attracted widespread interest since World War II. A number of readability "yardsticks" have been devised, some of which distinguish two elements in readability: reading ease and reading interest.[30] While different "yardsticks" rely on different units of measurement, the factors listed by Robert Gunning [31] include those most often taken into account:

Average sentence length in words
Percentage of simple sentences
Percentage of strong verb forms
Portion of familiar words
Portion of abstract words
Percentage of personal references
Percentage of long words

This current emphasis on readability as a central aim in writing has undoubtedly helped to reactivate the attack on jargon, long, windy introductions, awkward inversions and otherwise involved sentence structure, pretentious diction, "fine writing," and verbiage generally. The uncritical acceptance of all that has been written in behalf of readability may, however, lead to two misconceptions: an expectation that the art of writing can be reduced to a formula and a disregard of the fact that the scientific writer has an obligation to his material as well as to the reader. (See Appendix A, p. 415.)

IV. ANALYSIS OF THE STYLE OF A SCIENTIFIC PAPER

"The Great Piltdown Hoax," [32] an article reprinted in part here for purposes of stylistic analysis, affords ample evidence that scientific writing need not be dull. The author has evidently addressed

[29] Rudolf Flesch, *The Art of Readable Writing*, New York, Harper & Brothers, 1949, p. 198.
[30] Rudolf Flesch, *How to Test Readability*, New York, Harper & Brothers, 1951, pp. 5, 9.
[31] By permission from *The Technique of Clear Writing*, pp. 32-33, by Robert Gunning. Copyright 1952. McGraw-Hill Book Company, Inc.
[32] William L. Straus, Jr., "The Great Piltdown Hoax," *Science*, 119:265-69, February 26, 1954.

his review not to the specialist but to readers generally who are interested in the history of scientific thought. With this wider circle of readers in mind, the author has undoubtedly permitted himself adjectives—"astounding," "inexplicable"—which would be inappropriate in a report of experimental results to a group of specialists. At times a tinge of irony verging on humor colors the phrasing "a veritable bone of contention," "polite anthropological society," "the *disjecta membra* of the Piltdown 'dawn man,' " as if the author were mindful that it is a chronicle of scientific fallibility he is recounting. While this article could not serve as a model for all types of scientific writing, it is admirably adapted to its purpose.

The analysis which is offered following the article permits a detailed comparison of the two introductory paragraphs and paragraph 15, which is more theoretical. The analysis covers principally sentence structure and diction with some attention to qualities of style. In the calculation of the length of sentences and paragraphs each proper name has been counted as one word, as has each foreign phrase.

THE GREAT PILTDOWN HOAX

William L. Straus, Jr.

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[1] When Drs. J. S. Weiner, K. P. Oakley, and W. E. Le Gros Clark (*1*) recently announced that careful study had proven the famous Piltdown skull to be compounded of both recent and fossil bones, so that it is in part a deliberate fraud, one of the greatest of all anthropological controversies came to an end. Ever since its discovery, the skull of "Piltdown man"—termed by its enthusiastic supporters the "dawn man" and the "earliest Englishman"—has been a veritable bone of contention. To place this astounding and inexplicable hoax in its proper setting, some account of the facts surrounding the discovery of the skull and of the ensuing controversy seems in order.

[2] Charles Dawson was a lawyer and an amateur antiquarian who lived in Lewes, Sussex. One day, in 1908, while walking along a farm road close to nearby Piltdown Common, he noticed that the road had been repaired with peculiar brown flints unusual to that region. These flints he subsequently learned had come from a gravel pit (that turned out to be of Pleistocene age) in a neighboring farm. Inquiring there for fossils, he enlisted the interest of the workmen, one of whom, some time later, handed Dawson a piece of an unusually thick human parie-

tal bone. Continuing his search of the gravel pit, Dawson found, in the autumn of 1911, another and larger piece of the same skull, belonging to the frontal region. His discoveries aroused the interest of Sir Arthur Smith Woodward, the eminent paleontologist of the British Museum. Together, during the following spring (1912), the two men made a systematic search of the undisturbed gravel pit and the surrounding spoil heaps; their labors resulted in the discovery of additional pieces of bone, comprising—together with the fragments earlier recovered by Dawson—the larger part of a remarkably thick human cranium or brain-case and the right half of an apelike mandible or lower jaw with two molar teeth *in situ* (*2*). Continued search of the gravel pit yielded, during the summer of 1913, two human nasal bones and fragments of a turbinate bone (found by Dawson), and an apelike canine tooth (found by the distinguished archeologist, Father Teilhard de Chardin) (*3*). All these remains constitute the find that is known as Piltdown I.

[3] Dawson died in 1916. Early in 1917, Smith Woodward announced the discovery of two pieces of a second human skull and a molar tooth (*4*). These form the so-called Piltdown II skull. The cranial fragments are a piece of thick frontal bone representing an area absent in the first specimen and a part of a somewhat thinner occipital bone that duplicates an area recovered in the first find. According to Smith Woodward's account, these fragments were discovered by Dawson early in 1915 in a field about two miles from the site of the original discovery.

[4] The first description of the Piltdown remains, by Smith Woodward at a meeting of the Geological Society of London on December 18, 1912 (*2*), evoked a controversy that is probably without equal in the history of paleontological science and which raged, without promise of a satisfactory solution, until the studies of Weiner, Oakley, and Clark abruptly ended it. With the announcement of the discovery, scientists rapidly divided themselves into two main camps representing two distinctly different points of view (with variations that need not be discussed here) (*5*).

[5] Smith Woodward regarded the cranium and jaw as belonging to one and the same individual, for which he created a new genus, *Eoanthropus*. In this monistic view toward the fragments he found ready and strong support. In addition to the close association within the same gravel pit of cranial fragments and jaw, there was advanced in support of this interpretation the evidence of the molar teeth in the jaw (which were flatly worn down in a manner said to be quite peculiar to man and quite unlike the type of wear ever found in apes) and, later, above all, the evidence of a second, similar individual in the second set of skull fragments and molar tooth (the latter similar to those imbedded in the jaw and worn away in the same unapelike manner). A few individuals (Dixon [*6*], Kleinschmidt [*7*], Weinert

[*8*]), moreover, have even thought that proper reconstruction of the jaw would reveal it to be essentially human, rather than simian. Reconstructions of the skull by adherents to the monistic view produced a brain-case of relatively small cranial capacity, and certain workers even fancied that they had found evidences of primitive features in the brain from examination of the reconstructed endocranial cast (*9, 10*)—a notoriously unreliable procedure; but subsequent alterations of reconstruction raised the capacity upward to about 1400 cc—close to the approximate average for living men (*10*, p. 596).

[6] A number of scientists, however, refused to accept the cranium and jaw as belonging to one and the same kind of individual. Instead, they regarded the brain-case as that of a fossil but modern type of man and the jaw (and canine tooth) as that of a fossil anthropoid ape which had come by chance to be associated in the same deposit. The supporters of the monistic view, however, stressed the improbability of the presence of a hitherto unknown ape in England during the Pleistocene epoch, particularly since no remains of fossil apes had been found in Europe later than the Lower Pliocene. An anatomist, David Waterston, seems to have been the first to have recognized the extreme morphological incongruity between the cranium and the jaw. From the announcement of the discovery he voiced his disbelief in their anatomical association (*11*, p. 150). The following year (1913) he demonstrated that superimposed tracings taken from radiograms of the Piltdown mandible and the mandible of a chimpanzee were "practically identical"; at the same time he noted that the Piltdown molar teeth not only "approach the ape form, but in several respects are identical with them." He concluded that since "the cranial fragments of the Piltdown skull, on the other hand, are in practically all their details essentially human . . . it seems to me to be as inconsequent to refer the mandible and the cranium to the same individual as it would be to articulate a chimpanzee foot with the bones of an essentially human thigh and leg" (*12*). . . .

[7] A third and in a sense neutral point of view held that the whole business was so ambiguous that the Piltdown discovery had best be put on the shelf, so to speak, until further evidence, through new discoveries, might become available. I have not attempted anything resembling a thorough poll of the literature, but I have the distinct impression that this point of view has become increasingly common in recent years, as will be further discussed. Certainly, those best qualified to have an opinion, especially those possessing a sound knowledge of human and primate anatomy, have held largely—with a few notable exceptions—either to a dualistic or to a neutral interpretation of the remains, and hence have rejected the monistic interpretation that led to the reconstruction of a "dawn man." Most assuredly, and contrary

to the impression that has been generally spread by the popular press when reporting the hoax, "Eoanthropus" has remained far short of being universally accepted into polite anthropological society. . . .

[8] In 1892, Carnot, a French mineralogist, reported that the amount of fluorine in fossil bones increases with their geological age—a report that seems to have received scant attention from paleontologists. Recently, K. P. Oakley, happening to come across Carnot's paper, recognized the possibilities of the fluorine test for establishing the relative ages of bones found within a single deposit. He realized, furthermore, that herein might lie the solution of the vexed Piltdown problem. Consequently, together with C. R. Hoskins, he applied the fluorine test to the "Eoanthropus" and other mammalian remains found at Piltdown (*20*). The results led to the conclusion that "all the remains of *Eoanthropus* . . . are contemporaneous"; and that they are, "at the earliest, Middle Pleistocene." However, they were strongly indicated as being of late or Upper Pleistocene age, although "probably at least 50,000 years" old (*19*). Their fluorine content was the same as that of the beaver remains but significantly less than that of the geologically older, early Pleistocene mammals of the Piltdown fauna. This seemed to increase the probability that cranium and jaw belonged to one individual. But at the same time, it raised the enigma of the existence in the late Pleistocene of a human-skulled, large-brained individual possessed of apelike jaws and teeth—which would leave "Eoanthropus" an anomaly among Upper Pleistocene men. To complete the dilemma, if cranium and jaw were attributed to two different animals—one a man, the other an ape—the presence of an anthropoid ape in England near the end of the Pleistocene appeared equally incredible. Thus the abolition of a Lower Pleistocene dating did not solve the Piltdown problem. It merely produced a new problem that was even more disturbing.

[9] As the solution of this dilemma, Dr. J. S. Weiner advanced the proposition to Drs. Oakley and Clark that the lower jaw and canine tooth are actually those of a modern anthropoid ape, deliberately altered so as to resemble fossil specimens. He demonstrated experimentally, moreover, that the teeth of a chimpanzee could be so altered by a combination of artificial abrasion and appropriate staining as to appear astonishingly similar to the molars and canine tooth ascribed to "Piltdown man." This led to a new study of all the "Eoanthropus" material that "demonstrated quite clearly that the mandible and canine are indeed deliberate fakes" (*1*). It was discovered that the "wear" of the teeth, both molar and canine, had been produced by an artificial planing down, resulting in occlusal surfaces unlike those developed by normal wear. Examination under a microscope revealed fine scratches such as would be caused by an abrasive. X-ray examination

of the canine showed that there was no deposit of secondary dentine, as would be expected if the abrasion had been due to natural attrition before the death of the individual.

[10] An improved method of fluorine analysis, of greater accuracy when applied to small samples, had been developed since Oakley and Hoskins made their report in 1950. This was applied to the Piltdown specimens. . . . The results clearly indicate that whereas the Piltdown I cranium is probably Upper Pleistocene in age, as claimed by Oakley and Hoskins, the attributed mandible and canine tooth are "quite modern." As for Piltdown II, the frontal fragment appears to be Upper Pleistocene (it probably belonged originally to Piltdown I cranium), but the occipital fragment and the isolated molar tooth are of recent or modern age. . . .

[11] In conclusion, therefore, the *disjecta membra* of the Piltdown "dawn man" may now be allocated as follows: (1) the Piltdown I cranial fragments (to which should probably be added Piltdown II frontal) represent a modern type of human brain-case that is in no way remarkable save for its unusual thickness and which is, at most, late Pleistocene in age; (2) Piltdown I mandible and canine tooth and Piltdown II molar tooth are those of a modern anthropoid ape (either a chimpanzee or an orangutan) that have been artificially altered in structure and artificially colored so as to resemble the naturally colored cranial pieces—moreover, it is almost certain that the isolated molar of Piltdown II comes from the original mandible, thus confirming Hrdlička's (*18*) earlier suspicion; and (3) Piltdown II occipital is of recent human origin, with similar counterfeit coloration.

[12] Weiner, Oakley, and Clark conclude that "the distinguished palaeontologists and archaeologists who took part in the excavations at Piltdown were the victims of a most elaborate and carefully prepared hoax" that was "so extraordinarily skilful" and which "appears to have been so entirely unscrupulous and inexplicable, as to find no parallel in the history of palaeontological discovery."

[13] It may be wondered why forty years elapsed before the hoax was discovered. Two factors enter here: first, there was no reason at all to suspect the perpetration of a fraud, at least, not until fluorine analysis indicated the relative recency of all the specimens, thus making the association of a human cranium and an anthropoid-ape jaw, either anatomically or geologically, hardly credible; and, second, methods for *conclusively* determining whether the specimens were actual fossils or faked ones, short of their wholesale destruction, were developed only in recent years (it will be recalled that even the fluorine-estimation method used by Oakley and Hoskins a few years ago was inadequate for detecting a significant difference between brain-case and jaw). . . .

[14] The ready initial acceptance of the Piltdown discovery at its face value, at least by a majority of interested scientists, can probably be attributed to the philosophical climate that invested the problem of human evolution at that time. In September, 1912, before the announcement of the discovery of "Piltdown man," the distinguished anatomist, Elliot Smith, in an address before the Anthropological Section of the British Association for the Advancement of Science at Dundee (*22*), expressed a prevailing point of view when he developed the theory that the brain led the way in the evolution of man and that modification of other parts of the body followed. Thus the stage was set for the ready acceptance of the Piltdown fragments as constituting a single individual, a "dawn man" possessing a human cranium housing a human brain, but with phylogenetically laggard, hence simian, jaws and teeth. . . .

[15] Recent finds of fossil men and other primates, however, indicate that it is the brain that was the evolutionary laggard in man's phylogeny; indeed, the studies of Tilly Edinger (*24*) of the phylogeny of the horse brain suggest that this may well be a general rule in mammalian evolution. It was such concepts as this, leading to a change in philosophical climate, that evoked an increasing skepticism toward the validity of the monistic interpretation of the Piltdown fragments and led in turn to what appears to have been the prevailing recent opinion, namely, that the fragments should, as expressed in 1949 by Le Gros Clark (*25*), "be laid aside without further comment until more evidence becomes available." This view, enhanced by the redating of the remains by Oakley and Hoskins, provided the proper psychological setting for the *coup de grâce* delivered by Weiner, Oakley, and Clark.

[16] As the three latter point out, the solution of the Piltdown enigma greatly clarifies the problem of human evolution. For "Eoanthropus," both morphologically and geologically, just simply did not fit into the picture of human evolution that has gradually been unfolding as the result of paleontological discoveries throughout the world.

[17] The Piltdown story is a significant one in the history of ideas, more particularly as it bears on the concept of the precise course of human evolution. For, if man's biological history be likened to a book, it is seen to be composed of both blank and written pages and, by those who note them carefully, many if not most of the written ones will be seen to be in the nature of palimpsests—pages that have been rewritten after their original writing has been rubbed out. Of this, the Piltdown affair is a striking demonstration. It is a demonstration, furthermore, that the palimpsest nature of the pages of man's history is not always due directly to new fossil discoveries but can also result

from changes in the philosophical climate of the science. That this phenomenon is peculiar to anthropology, however, is seriously to be doubted.

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Sentence Structure

	Simple	*Compound*	*Complex*	*Compound-complex*	*Total*
Par. 1	2	0	1	0	3
Par. 2	3	1	5	0	9
Par. 15	1	0	1	1	3

The author's liking for periodic sentences (sentences in which the main idea or principal clause comes at the end) is also evident, as

in the three sentences of paragraph 1 and the second sentence of paragraph 2.

Sentence Length (in words)

	Longest sentence	*Shortest sentence*	*Average length*
Par. 1	47	28	35
Par. 2	71	12	29
Par. 15	66	29	47

A few extremely long sentences raise the average sentence length. The effective use of short sentences to open and close paragraph 2 should be noted.

Diction

PARAGRAPH 1

Total number of words: 105

Technical terms: Piltdown, fossil, anthropological. Total—3, about 3 per cent.

Words with "human interest": famous, skull, bones, deliberate, fraud, greatest, controversies, discovery, man, enthusiastic, supporters, "dawn man," "earliest Englishman," veritable, bone of contention, astounding, inexplicable, hoax, setting. Total—21, about 20 per cent.

Foreign words: 0

PARAGRAPH 2

Total number of words: 255

Technical terms: Pleistocene, parietal, frontal, paleontologist, cranium, mandible, molar, nasal, turbinate, canine, archeologist, *in situ*. Total—12, about 4.7 per cent.

Words with "human interest": lawyer, amateur, antiquarian, walking, farm, road, peculiar, brown, flats, unusual, region, gravel, pit, neighboring, inquiring, interest, unknown, human, bone, search, autumn, skull, discoveries, aroused, comment, spring, spoil, heaps, labors, fragments, remarkably, brain-case, apelike, jaw, teeth,

yielded, summer, distinguished, remains, find. Total—40, about 15 per cent.

Foreign phrase: *in situ.*

PARAGRAPH 15

Total number of words: 142

Technical terms: primates, phylogeny, mammalian, Piltdown. Total—4, about 3 per cent.

Words with "human interest": recent, finds, men, brain, laggard, horse, suggest, rule, change, climate, fragments, comment, evidence, view, remains, setting. Total—16, about 9 per cent.

Foreign phrase: *coup de grâce.*

Unlike paragraphs 1 and 2, paragraph 15 contains a number of noticeably long or abstract words: evolutionary, concepts, philosophical, skepticism, validity, monistic.

Comments

From the foregoing analysis and from further examination of the article the following generalizations seem justified.

1. The preference for simple or complex rather than compound sentences is a mark of a mature style. In contrast the average student paper would probably contain a number of straggly compound sentences.

2. Though a few sentences are extremely long, their length does not impair readability because the length of sentences is varied, minor considerations are skillfully subordinated to major ones, and sentence rhythm is maintained.

3. Human interest is not lacking although this article was considered suitable for publication in a journal directed almost entirely to scientific readers.

4. In spite of the use of everyday, concrete words, the tone of the article is detached rather than subjective or personal. There are no direct references to the author in either first or third person.

5. The diction is clear and precise, and the movement of the sentences direct and straightforward. There is no evidence of shoptalk or jargon.

6. The style varies slightly as the immediate purpose changes in different paragraphs of the article. The opening paragraph, for ex-

ample, designed to introduce the subject to the reader, is less technical than paragraph 5, which sums up the contrasting theories by which scientists interpreted the Piltdown remains.

At the opening of this chapter it was noted that style in scientific writing should be unobtrusive. This does not mean, however, that style in scientific writing is unimportant. On the contrary, style is of great consequence in all expository writing. Perhaps the most famous definition of style is Buffon's "Style is the man." Generalized to apply to scientific writing such a definition would imply that scientific style is expressive of the scientific attitude of mind.

STUDY SUGGESTIONS

1. Contrast the style of these two sentences: (a) Lillie represented the American Society of Zoologists for four years in the Division of Biology and Agriculture, serving as Vice Chairman of the Division in the year 1921-22 and as chairman the following year. (b) Lillie was active during this period in scientific organizations and his abilities were recognized by elevating him to a number of offices. By the standards of scientific writing, which is to be preferred?
2. Dwight E. Gray says (*Journal of Chemical Education*, 25:226-28, April 1948) that "somewhere in his consideration of organization the author should decide upon a sensible title" and cites as bad examples two reports received in the laboratory, one called "Final Report on Item No. 2" and the other "The Most Important Research Work of the Last Time and Proposals about Reports Still to Be Written." What is wrong with these titles and what should titles covering comparable subject matter include?
3. Point out the faults in style in the following statements and suggest revisions: (a) The article contrasted the problems of the rural countryside with those of the urban city. (b) The property reverted back to the original owner. (c) Almost all of the cells present are small in size. (d) Illumination at controlled thermal temperature was obtained by the use of a light-transmitting quartz rod. (e) The availability of the necessary raw materials is essentially negligible. (f) A death rate of almost 35 per cent is claimed by this deadly disease. (g) Blood coagulation has puzzled medicine for many years.
4. Revise the following sentences: (a) However, he does not overemphasize wit; observe this sentence, which illustrates his style. (b) The summary condensed what the lecturer covered for the student's convenience. (c) The mesenchymal parts are reduced in size which is more marked in some parts of the bodies than in others. (d) If the

two instruments are examined closely it will be seen that they are not alike but differ. (e) Nowhere does the author make reference to this occurrence, instead one finds vague generalities. (f) Bearing this in mind, the weaknesses of theory are obvious.

5. Suggest changes to improve the diction of the following sentences: (a) He brings out the concept of science as being too indifferent to human values. (b) This is a comparatively minor error and one of little importance. (c) The author has prepared this as the first volume of an anticipated eight-volume work. (d) Numerous phenomena which revolve around us are taken for granted. (e) His statement inferred that he had begun the project some time before.
6. Proofread the paragraph below, correcting all errors in spelling, punctuation, and usage. Make no unnecessary changes.

   Although this problem has long been familiar to members of the medical profession; it is difficult to find it's nucelus and to seperate its essential from its nonessential elements. It is all to easy to let our very familarity with the subject prevent us making a vigorous attack on the problem. The principle issues have been slow to develope, their seriousness would now be difficult to exagerate. Before we can hope to affect a solution we must undo some of the affects of yesterdays neglect. A first step is to breifly define the boundries of our present knowledge and of course establishing a criteria by which we can evaluate a new possibility as they arise.

7. Apart from the errors you have corrected in the foregoing paragraph, what do you find to criticize in its style?

CHAPTER 9

TECHNIQUES OF EXPOSITION

> *I could wish that it [instruction] were more expository, less polemical, and above all less dogmatic.* JOHN STUART MILL, Inaugural Address.

I. THE PLACE OF EXPOSITION IN WRITING

In the process of writing there are certain products of training and experience which the writer utilizes but which he does not communicate directly to the reader. Such terms as *exposition, statement of purpose, paragraph structure,* and *method of development* seldom appear in the finished paper, but the knowledge they represent guides the writer as he prepares it. This technical knowledge of the writer's craft often makes the difference between an effective and an ineffective piece of work.

Fundamental in the theory of writing is the division of prose discourse into four forms: *narration, description, exposition,* and *persuasion.* Though all four are used by the scientific writer, his greatest concern is with exposition.

A. Exposition Defined

The distinction among the four forms of writing is arrived at by defining the author's intention. If the dominant intent is to relate a series of events with regard for chronological order, the writing is classified as narration. If the intent is to convey to the mind of a reader a sensory or emotional impression—a "mental picture"—the writing is description. If the intent is to win the reader to the writer's way of thinking, it is persuasion (sometimes termed *argumentation*). If the intent is to explain facts, theories, or ideas, it is exposition. The derivative meaning of *exposition*—a setting forth—is literally realized in public expositions where the products of art and industry are arranged and displayed. Exposition in writing is a setting forth also, but it is the information and ideas of the writer which are arranged and presented for the reader's consideration.

Expository writing is further characterized by its inherent appeal to reason. Unlike narrative which establishes a time order, or description which is guided either by an impressionistic or a spatial order, or persuasion which follows the order that will gain the desired support (which may of course be also the logical order), exposition is committed by its nature to a logical development. It proceeds from the whole to the parts, from the parts to the whole, from cause to effect, from purpose to method, and from evidence to conclusion. When the physical relationships of time and space become consequential in exposition, it is because they are important to the rational concept which is being developed in the reader's mind.

B. Exposition and the Other Forms of Writing

If exposition is to be fully understood, its relationship to the other forms of writing must be clear. Little difficulty arises in distinguishing exposition from *narration.* However, passages of narrative often appear in exposition as subsidiary means of explanation. The writer may narrate an incident to illustrate a point or to dramatize a result. What purpose, for example, may be ascribed to the writer of the following paragraphs?

> A puff of wind comes down the street. An old newspaper stirs in the gutter, jumps up on the sidewalk, spirals up to second-story height and flaps about there for a moment; then, with a new burst of energy,

> it sweeps upward again, and when you last see it, it is soaring high above the roof tops, turning over and over, blinking in the sunlight.
>
> The wind has picked up a piece of paper and blown it away. What of it? A generation ago, in philosophical discourse, one might have chosen this as an example of an event completely void of significance, completely chance. But not in the air age. The tiny occurrence demonstrates an important fact concerning the air ocean—one that is only now becoming the practical knowledge of practical airfaring men: there are winds which blow neither east nor west, neither north nor south, but in the third dimension: straight up.[1]

In other contexts the first of the preceding paragraphs might serve a writer in various ways. The last sentence of the second paragraph, however, establishes the passage as exposition and makes it clear that the significance of the simple incident as related here lies in its demonstration of a principle of aeronautics. The concrete illustration, because of its greater appeal to the general reader, has been placed before the statement of abstract principle.

The distinction between *description* and exposition is often difficult to define. There are two quite different types of description: first, factual or scientific description, which is closely related to exposition, and, second, the more subjective type of description which is met with in the short story or novel. The passage quoted below illustrates the second type. It creates a mood, an impression, as well as a sensory image. The words are chosen for their sound and connotative values as well as for the meanings they convey. The situation is specific and the treatment highly subjective.

> . . . I wandered out, pursued by distressful thoughts, into the gardens, those famous gardens of Stein, in which you can find every plant and tree of tropical lowlands. I followed the course of the canalised stream, and sat for a long time on a shaded bench near the ornamental pond, where some waterfowl with clipped wings were diving and splashing noisily. The branches of casuarina-trees behind me swayed lightly, incessantly, reminding me of the soughing of fir-trees at home.[2]

In contrast, the following example of scientific description conveys factual knowledge, and the words are chosen from an established scientific terminology to convey exact technical meanings. The situa-

[1] Wolfgang Langewiesche, "Winds That Blow Straight Up," *Harper's Magazine*, 191:107, August 1945.

[2] Joseph Conrad, *Lord Jim*, Garden City, N. Y., Doubleday, Page & Company, 1925, p. 349. Used with permission of J. M. Dent & Sons, London.

tion is generalized and the treatment objective. It will be noted that the sentences are not complete; the verb *to be* is omitted throughout.

LINDEN [3]

Tilia americana

A large symmetrical tree 50-70 and in favorable conditions of forest growth 130 feet high, with a trunk diameter of 3 or more feet, the stem rising straight to the round-topped head, the branches horizontal, slender, often drooping. Bark deep brownish gray, firm, scored perpendicularly with elongated fissures, the ridges confluent, narrow, flat-topped marked with transverse cracks; the twigs slender, smooth, ruddy brown, and often zig-zagged, slightly dotted.

The leaves perfectly heart-shaped, sharp-pointed, sometimes oblique or asymmetrical, large, 4-7 inches long, coarsely double-toothed, prominently yellow-veined, light green above, scarcely paler beneath . . . with few white hairs scattered on the general surface, the stem about ⅓ of the length of the leaf. Flowers with 5 cream white petals and sepals, sweet-scented, a scale alternating with each petal; blooming in May-June. Fruit spherical, about the size of a pea, borne singly or few in a cluster on a common stalk merged half-way in a leaflike narrow wing or bract; often persistent on the tree until mid-winter.

Like this example, much scientific writing is descriptive. In the development of every natural science, time has been devoted to the minute description of the phenomena with which the science deals, and to this end a precise descriptive vocabulary has been accumulated. The botanist, for example, may choose from *oval*, *elliptical*, *linear*, *deltoid*, *ovate*, *lanceolate*, and a number of other terms to describe the general outline of a leaf.[4]

The distinction between exposition and *persuasion* is at times difficult to establish since a tinge of persuasion often colors otherwise expository material. (See Chapters 11 and 12.) While a writer is free to employ narration and description in exposition, if he introduces a perceptible note of persuasion, his writing is better classified

[3] F. Schuyler Mathews, *Field Book of American Trees and Shrubs*, New York, G. P. Putnam's Sons, 1915, pp. 322-23.

[4] Scientific description, in contrast to literary or impressionistic description, is sometimes classified as a form of exposition. At the other extreme are those who maintain that "the primary aim of Science is the concise description of the knowable universe" in the sense that science deals with verifiable phenomena rather than with ultimate causes. See J. Arthur Thomson, *Introduction to Science*, New York, Henry Holt and Company, 1911, p. 35 ff.

as persuasion. This leaves to persuasion a wide field, and persuasion —both for good and ill—is becoming an increasingly large factor in our national life. In contrast to the honest use of persuasion is the activity of the propagandist who disguises his motives and the sources of his material.

In the first of the two following examples of legitimate persuasion an anecdote disarms the reader.

> At present, however, a certain amount of criticism of both historians and social scientists for their indifference to each other's work is justified. Perhaps no single historian or social scientist deserves all of the reproof contained in this little volume. There is a story (*se non è vero, è ben trovato*) told about Charles Dana as a young reporter, which may be appropriate here. Asked to cover the United States Senate, he had expressed the opinion that everyone in the Senate was a fool. The editor, realizing that such an opinion would anger every member of the Senate, advised him to change his statement to read that every senator but one was a fool. The revised statement, the editor explained, would have the approval of every senator. Since I readily admit that the "historian" and the "social scientist" rebuked in the following pages are merely straw men, made up out of frequently obsolescent or unwanted bits that probably belong to no one person altogether, I hope many historians and social scientists will be tolerant of my opinion, while admitting that certain of my criticisms apply to certain of their colleagues.[5]

In the second example the method is partially that of factual exposition, but the persuasive tone is evident in such phraseology as "respective claims," "narrowly individualistic outlook," "if any event must be singled out," "if any event need be singled out."

> The respective claims of Newton and his continental contemporary Leibniz to be regarded as the author of the infinitesimal calculus have given rise to considerable discussion in which national sentiment has played no small part. Such controversies reflect a narrowly individualistic outlook on the history of science. Nobody invented the calculus. It was the co-operative product of a group of men. If any event must be singled out as the beginning of the differential calculus, credit would seem to be due pre-eminently to Barrow, who was Newton's teacher. If any event need be singled out as the beginning of the integral calculus, it was the recognition that the determination of an

[5] Louis Gottschalk, "The Historian and the Historical Document," *The Use of Personal Documents in History, Anthropology and Sociology*, New York, Social Science Research Council, Bulletin 53, 1945, p. 5.

> area is the same thing as solving a differential equation, and the credit for this step is mainly due to Leibniz, who also introduced the *dx* symbolism. Newton's main contribution was to show how differential equations could be used to interpret the observed truths of mechanics, astronomy, and optics, and so to emphasize the extraordinary usefulness of the new methods.[6]

Only a small part of all exposition follows the tradition of the literary essay. A larger part consists of reports, reviews, and short articles varied in length and pattern to suit the immediate purpose.

II. THE EXPOSITORY PARAGRAPH

Whatever the length of the entire paper, the accepted unit of exposition is the paragraph. In order to handle paragraphs competently the writer must realize that they have two functions which are quite different. One is to present the material in units of thought and development which can be readily grasped in their entirety by the reader. The other function is to provide physical and mental breaks for the reader in order to spare him the effort of too long continued attention.

A. Length of Paragraphs

The paragraph length which will best serve these ends naturally varies with the subject matter and the circumstances. Light journalistic articles usually have shorter paragraphs than do heavier articles to which the reader is expected to give more serious attention. However, in brief presentations of some types of very technical material, short paragraphs are customary. For most purposes considerable variety in paragraph length is permissible and even desirable, and it is not unusual to find paragraphs within a single article ranging in length from fifty to two hundred words.

Some writers tend habitually to compose short, choppy paragraphs; others to compose long, tedious paragraphs. Each of these tendencies is annoying to the reader who must be either constantly shifting his attention or fixing it for excessively long periods. Even if a paragraph seems like a unit to the writer, the units may still be too short or too long to be readily assimilated by the reader. The

[6] Lancelot Hogben, *Mathematics for the Million*, New York, W. W. Norton & Company, Inc., 1937, p. 542.

recommended practice is to combine short paragraphs or to develop them more fully and to divide extremely long paragraphs or to streamline them by making omissions or by employing more efficient expression.

B. Structure of Paragraphs

There are two ways of undertaking the construction of a paragraph. If space is available for the expansion and development of the writer's ideas, the paragraph is primarily a developmental unit elaborating the basic thought. In a condensed style such as that demanded in some types of scientific papers, the paragraph is essentially an assembling unit.

1. The Paragraph as an Assembling Unit

As an assembling unit the paragraph is used to group ideas or facts which are closely related, but such a paragraph affords little opportunity for elaboration or extended discussion. The first of the two following examples brings together facts of general interest concerning amber.

> Amber is a translucent substance, yellowish, brownish, or reddish in color, formed by the fossilization of resin exuded from ancient trees. It is found in the region of the Baltic Sea, Sicily, Burma, India, and elsewhere. When rubbed, it electrostatically attracts small pieces of paper, chaff, and other light materials. This property of amber first provided man with an opportunity to observe static electricity in a simple form.[7]

The second example lists the types of scientists needed in the Southwest Pacific during World War II.

> The types of scientific men that officers in the Southwest Pacific were eager to obtain as they laid elaborate plans to conquer climate, distance, terrain, equipment, and supply in chopping off the military tentacles of Japan were these: medical experts to study their second most important enemy, malaria, and to cure the fungus infections that sapped morale; electronics engineers to test a homing torpedo developed in the field; radio and radar research men to study propagation of radio waves and to design lightweight air-transportable radar gear; counter-measures experts to find ways of jamming enemy radar; engineers to assist in introducing an aerial bomb launched backwards

[7] "Amber," *Medical Radiography and Photography*, 29(1):cover 2, 1953.

to offset its forward path so that it drops on a target directly below the point of release; biologists whose skills could be used against tiny marine organisms that were destroying wooden craft and docks in tropical waters; chemists and chemical engineers to study the behavior of poison gases and smokes in thickly forested, humid areas; physicists to produce a fuze that would cause a bomb to explode about thirty feet above the ground; experts in time and motion analysis to unwind snarls in handling communications; men to analyze bottlenecks in transportation, failure of equipment, effectiveness of antiaircraft fire, and tactics of our air and surface craft in spotting and obliterating Japanese submarines.[8]

2. *The Paragraph as a Developmental Unit*

The expository paragraph as a developmental unit offers a further explanation of the central idea of the paragraph, which is often expressed in a topic sentence. The concept of *development* in writing is analogous to the concept of development in biology. A point emphasized in biological studies is that though the potentialities of the adult organism are present in the germ cell from which it develops, these potentialities are not realized until the organism has grown to the adult stage. Similarly the potentialities of a paragraph are present in the central or germinal idea, but are not realized until the idea has been developed into the completed paragraph. Thus development does not mean mere repetition or extension any more than biological development is a simple multiplication of cells.

It is the writer's responsibility to choose the means of exposition which will bring the central idea of the paragraph to its full development. Illustrations may be offered, terms defined, situations analyzed, entities classified or compared, evidence presented and inferences drawn, causes and effects traced, misconceptions corrected, or some of these means of exposition may be employed in combination. While the following examples of expository paragraphs have been selected to show different methods of development, the order of sentences within the paragraph and the means of gaining coherence and emphasis (see Section III-C) should also be noted.

The following paragraph illustrates development by *example*. In this instance concrete illustrations are particularly effective since the

[8] Lincoln R. Thiesmeyer and John E. Burchard, *Combat Scientists*, Boston, Little, Brown and Company and Atlantic Monthly Press, 1947, p. 34.

central idea of the paragraph, expressed in the opening sentence, is highly abstract.

> Let me illustrate the predictive nature of abstract laws by some examples. The law that fire is hot goes beyond the experiences on which this law was established and which belong to the past; it predicts that whenever we shall see a fire it will be hot. The laws of the motion of the stars permit us to predict future positions of the stars and include predictions of observations like eclipses of the sun and the moon. The atomic theory of matter has led to chemical predictions, verified in the construction of new chemical substances; in fact, all industrial applications of science are based on the predictive nature of scientific laws, since they employ scientific laws as blueprints for the construction of devices that function according to a preconceived plan. Bacon had a clear insight into the predictive nature of knowledge when he coined his famous maxim: knowledge is power.[9]

The next example, developed by *definition,* first explains the varied uses of the word *document* and then indicates how the writer expects to use the term.

> The word *document* has been used by historians in several senses. On the one hand, it is sometimes used to mean any written source of historical information as contrasted with oral testimony or with artifacts, pictorial survivals and archaeological remains. On the other, it is sometimes reserved for only official and state papers such as treaties, laws, grants, deeds, etc. Still another sense is contained in the word *documentation,* which, as used by the historian *inter alios,* signifies any process of proof based upon any kind of source whether written, oral, pictorial or archaeological. For the sake of clarity, it seems best to employ the word *document* in the last, the most comprehensive definition, which is etymologically correct, using *written documents* and *official documents* to designate the less comprehensive categories. Thus *document* becomes synonymous with *source.*[10]

The type of analysis known as classification (see Chapter 5) is fundamental in science. The following paragraph, developed by *analysis,* deals with some of the problems of classifying odors.

> Any number of groupings of odors have been recorded. A great number of these are on the basis of "like" some well-known substance. Thus, they may be fruity, aromatic, balsamic, or alliaceous. On the more

[9] Hans Reichenbach, *The Rise of Scientific Philosophy,* Berkeley, University of California Press, 1951, pp. 80-81.
[10] Gottschalk, *op. cit.,* p. 12.

objectionable side are the empyreumatic or burnt odors, the caprylic or goaty odors, the fetid odors, and so on. Most of these classifications are convenient but scientifically are meaningless. The Crocker-Henderson classification and method of classification are at the present time the most acceptable. In this procedure, four fundamental odor sensations are recognized as being fragrant, acid, burnt, and caprylic. Each of these four qualities is arbitrarily registered on a scale of from 0 through 8. On this basis a substance without any odor would appear as 0000. Ethanol, for example, an odorous substance, is registered as 5414. This number indicates that ethanol is substantially fragrant, moderately acid, scarcely burnt, and fairly caprylic. A large number of substances have been registered on this basis, and the method is in common application among odor analysts.[11]

The two following selections, both developed by *comparison* and *contrast,* show the usefulness of this method in entirely different fields. The first concerns a problem in engineering, the second in the history of language.

There are two extreme conditions of lubrication—hydrodynamic and boundary. In the hydrodynamic condition, no contact exists between the rubbing solids; the parameters of importance involve only properties of the bulk liquid such as the viscosity, the density, the temperature coefficients of the viscosity and the density, the heat transfer coefficients, and those defining the geometry of the bearing system. In the boundary condition, contacts always exist between the rubbing solids, and the physical and chemical properties of the contacting surfaces are important. Hydrodynamic conditions of lubrication are usually desired in the operation of mechanisms because the coefficient of friction may be a few hundredths or less, and practically no wear occurs; boundary conditions of lubrications are avoided where possible, because of the resulting power consumption and the wearing, galling, or seizure of the rubbing solids.[12]

Any Chinese or Sinologist reading my brief description of [Egyptian] hieroglyphics will say to himself that it applies very well to Chinese characters. The Egyptians and the Chinese, working independently at two ends of the world, created two vast collections of word symbols. It is very interesting to compare the fruits of those

[11] By permission from *Air Pollution* by L. C. McCabe, Proceedings of the United States Technical Conference on Air Pollution, p. 249. Copyright 1952. McGraw-Hill Book Company, Inc.

[12] W. A. Zisman, "Present Problems and Future Trends in Lubrication," *Industrial and Engineering Chemistry,* 45:1406, July 1953. Reprinted by permission.

gigantic experiments. They started with pictograms as everybody would; moreover, the early Chinese and Egyptian pictograms of the same objects—sun, moon, mountains, water, rain, man, bird—were often analogous. As the two kinds of word symbols were standardized and simplified, and became more and more numerous, both peoples reached the same general conclusion—that each word should contain a phonetic element (sound sign) and a determinative one (sense sign). The Chinese did this very consistently. About 80 percent of their characters are made up of two parts, one of which is a clue to the sound, while the other (one of 214 "classifiers") is a clue to the meaning; generally speaking, the pronunciation of the classifier and the meaning of the phonetic element are disregarded.

Thus far the Chinese and Egyptian achievements are very much alike; there are fundamental differences between them, however—and what else could we expect, considering that the two nations were very unlike and had been submitted for thousands of years to very different physical and psychologic environments? In Egyptian writing the vowels are omitted and in speech they are frequently changed either to obey grammatical inflections or to indicate variations of meaning; in Chinese, on the contrary, the vowels belong to the root, have a semantic value, and are constant. The study of the meanings of Chinese words cannot be separated from the study of their sounds. One can see how alphabetic signs could eventually emerge from the Egyptian habit of script; they could not have emerged from the Chinese one. The Chinese word is always concentrated in a single character, more or less complex, yet meant to occupy the same space as any other character; the Egyptian word is more like a word in any syllabic script, it may cover more or less space.[13]

The next paragraph presents the evidence derived from one of Pasteur's experiments which showed that microorganisms are present in the air. Since the development of the paragraph is from *evidence to conclusion,* an inductive arrangement with the particulars preceding the generalization is appropriate.

Pasteur had already obtained direct evidence that germs of life are present in the air by concentrating the fine particles suspended in the atmosphere and observing them under the microscope. He had aspirated air through a tube in which was inserted a plug of guncotton which acted as a filter and intercepted the aerial germs. When at the end of the experiment, the guncotton plug was dissolved by placing it in a tube containing a mixture of alcohol and ether, the insoluble

[13] George Sarton, *A History of Science,* Cambridge, Harvard University Press, 1952, pp. 22-23.

dust separated from the solvent and settled in the bottom of the tube. Under the microscope, the sediment was found to contain many small round or oval bodies, indistinguishable from the spores of minute plants or the eggs of animalcules; the number of these bodies varied depending upon the nature of the atmosphere and in particular upon the height above the ground at which the aspirating apparatus had been placed. The dust recovered from the alcohol and ether solution always brought about a rapid growth of microorganisms when it was introduced into heated organic infusions, despite all precautions taken to admit only air sterilized by heat. It was thus clear that the fine invisible dust floating in the air contained germs which could initiate life in heated organic fluids.[14]

The following paragraph dealing with the causal connection between air movement and sound is developed by showing this *cause and effect* relationship in a number of different situations. Cause and effect paragraph development whether used with reference to a physical situation, as it is here, or to a social situation demands careful treatment such as Jeans has given it, since causal relationships are sometimes extremely complex.

We may seem to be still a long way from music. Actually we are very near, for it is precisely these little whirlwinds of air that are responsible for the production of sounds in wind instruments—without them our flutes and organ-pipes would cease to function. When whirlwinds are formed by the wind streaming past an obstacle of any kind, the formation of each little whirlwind gives a slight shock, both to the obstacle and to the air in its neighbourhood. If the wind blows in a continuous steady stream, these shocks are given to the air at perfectly regular intervals. We may then hear a musical note—it is what is often described as the "whistling of the wind," or the "wind whistle." Its pitch is of course determined by the frequency of the shocks to the air, and this is the number of whirlwinds formed per second. Experiment shews that a whirlwind is formed every time the wind passes over a distance equal to 5⅖ times the diameter of the obstacle, and this makes it possible to calculate the pitch of the note. Suppose, for instance, that we are at sea, with the wind blowing at 40 miles an hour through the rigging of half-inch ropes. Simple arithmetic shews that 40 miles an hour is 704 inches a second, so that the wind traverses 1408 diameters of the rope every second. Dividing this by 5⅖, we obtain 261 as the frequency of the note of the "wind whistle"—middle C of the piano. If the wind blows faster, whirlpools are formed

[14] René J. Dubos, *Louis Pasteur*, Boston, Little, Brown and Company, 1950, p. 170.

faster and the pitch of the wind whistle rises, the frequency being exactly proportional to the wind velocity. When the wind "howls," we hear the pitch of the note rising and falling, and its frequency at any instant gives a measure of the speed of the wind at that instant. If the obstacles which the wind meets are smaller, the pitch is higher; this is why we hear notes of high pitch when the wind blows over the telegraph wires on land, and still higher notes when it blows through stalks of corn or blades of grass.[15]

When the paragraphs offered as examples in this chapter are considered as a group, it is evident that the means of development in each instance have been chosen because of their appropriateness to the exposition of the central thought of the paragraph. Analyses of paragraph development should not lead to the impression that paragraphs are constructed according to formula or that all paragraphs can be placed in distinct categories. Many paragraphs are combinations of different methods of development, as is the concluding example which leads from definition into inference.

By far the most prolific sources of neutrons known are the nuclear chain reactors or piles. A nuclear reactor is an assembly of fissionable material (such as uranium, enriched U^{235}, Pu^{239}, or U^{233}) arranged in such a way that a self-sustaining chain reaction is maintained. In each fission process a number of neutrons (somewhere between one and three) are emitted. The requirement common to all reactors is that at least one of these neutrons must be available to produce another fission rather than escape from the assembly or be used up in some other type of nuclear reaction. Therefore, for a given type of reactor there is a minimum (or critical) size, below which the chain reaction cannot be self-sustaining. It is also necessary to avoid as much as possible the presence in the reactor of materials which consume neutrons in processes other than the fission reaction. This imposes a severe restriction on structural materials, coolants, and moderators.[16]

III. THE PLAN OF THE SHORT EXPOSITORY PAPER

In a well-planned short paper, each paragraph not only is adequately developed in itself but contributes its share to the development of the paper as a whole. Planning an expository paper involves

[15] Sir James Jeans, *Science and Music*, Cambridge, Eng., Cambridge University Press, 1937, pp. 126-27.

[16] Gerhart Friedlander and Joseph W. Kennedy, *Introduction to Radiochemistry*, New York, John Wiley & Sons, Inc., 1949, p. 101. Reprinted with permission.

certain steps: (1) defining the scope of the paper; (2) deciding on the topics to be treated; (3) determining the aspects of the paper which should receive the greatest emphasis; (4) arranging the topics in the order in which they will be taken up; and (5) anticipating the approximate number of paragraphs which will be needed to assemble or develop the topics to be considered. Anyone who has once sensed the difference between a planned and an unplanned paper will appreciate the value of plan in even a brief piece of writing.

A. Defining the Purpose

Before a successful plan can be made, the writer must have clearly in mind his specific purpose in writing the paper. While the general intent of all exposition is, of course, to explain, each individual paper has also its specific or immediate purpose, often called the controlling purpose because it guides the entire plan of the paper. In other words, the writer intends to explain a specific subject to the reader. Whether a formal statement of purpose appears in the paper or not, the writer should prepare such a statement for his own guidance. The following statements of purpose are representative of those which a writer might draw up for his own use before beginning a paper.

1. The purpose of this paper is to explain the principal differences between the Student Council's new by-laws and the old ones.
2. The purpose of this paper is to explain what is meant by the term *Mannich reaction.*
3. The purpose of this paper is to describe the nesting habits of the mourning dove.
4. The purpose of this paper is to explain the principal precautions observed in handling radioactive materials.
5. The purpose of this paper is to explain the principle of operation of the Diesel engine.

Once the writer has the controlling purpose of the paper clearly in mind, he is prepared to select and list the topics to be considered. This list of topics may be arranged in an order of climax (from those of lesser to those of greater importance), may proceed from the simple to the more complex, or may follow one of the many possible patterns of logical sequence (see Section I-A). A simple outline

of this sort is usually all that is needed for a short paper. (For a discussion of more extensive outlines see Chapter 5.)

B. Achieving Progression

Unlike longer papers, the short paper does not have a strongly defined introduction, central section, and conclusion. However, the opening, the advancement of the subject, and the ending combine to create a sense of *progression.* It is particularly important that the short paper open briskly and proceed without wasted motion to the conclusion. Many writers mistakenly try to adapt to this type of paper the long, formal introductions often used in extended scientific papers and reports. Such introductions are inappropriate in short papers. Similarly, if an attention-getting device such as an anecdote or quotation is used at the beginning, it should be brief and closely linked to the main point of the paper.

A roundabout introduction is an unfailing means of losing the reader's interest. For example, one report on the subject of on-the-job training programs in a certain industry began with a long discussion of the impracticality of many academic courses and the limited practicality of others. By the time the writer reached his real topic, all possible enthusiasm for the subject had been destroyed.

After the paper is under way there is less temptation to digress. While continuity should, of course, be maintained, elaborate transitional sentences are out of place. Bringing the paper to a conclusion is often difficult. Three common types of ineffective endings are the abrupt ending, the spun-out ending, and the tacked-on ending. Sometimes a summarizing sentence is all that is needed to round out the paper. Or the last sentence may re-emphasize the central thought developed in the paper. Again, a question may be an appropriate ending. Since the ending is the writer's last word with the reader, it should make a definite contribution to the purpose of the paper.

C. Maintaining Unity, Coherence, and Emphasis

If the purpose of a paper is well conceived and an efficient plan devised to achieve that purpose, it should not be difficult to insure the presence in the paper of the traditional rhetorical virtues—*unity, coherence,* and *emphasis.*

The word *unity* in composition implies singleness of effect, impact, or impression. Because of the limited scope of a short paper, it is essential that every element contribute directly to the controlling purpose. "In the whole composition," as Edgar Allan Poe expressed it, "there should be no word written, of which the tendency, direct or indirect, is not to the one pre-established design." [17]

A unified composition should be an organic whole in which each part is adequately developed in itself and also serves to advance the central theme; that is, the whole is more than the sum of the parts. It cannot be assumed that a paper is unified merely because it deals with a single subject. Though a thousand word paper on the geography of South America would deal with a single subject, it could scarcely attain unity; it would cover a diversity of topics which could not in brief compass be joined into a harmonious whole. The short paper should be restricted to a purpose which can be achieved within the projected length.

If the paper from the opening sentence advances consistently toward the ending, the paper will have a natural *coherence;* its different parts will hold together well. If sentences or paragraphs are inserted without reference to what precedes or follows, coherence is lost. The continuity will be strengthened by the use, where appropriate, of transitional expressions such as *however, hence, indeed, at the same time, on the contrary.* The repetition of key words and the effective use of pronouns also contribute to coherence. In a short paper these means of gaining coherence are preferred to the transitional sentence or paragraph.

Emphasis, the placing of stress on important ideas, should also be in part a natural result of the writer's interest in his subject and his feeling for what is consequential concerning it. It is well to remember in planning any unit of composition that the beginning and the end are the positions of prominence; the middle is less conspicuous. (For emphasis as a quality of style, see Chapter 8.)

IV. ANALYSES OF EXAMPLES

Much can be learned about the techniques of exposition by analyzing the work of skilled writers. With this understanding, three

[17] Edgar Allan Poe, *The Works of Edgar Allan Poe,* New York, W. J. Widdleton, 1849, Vol. III, p. 198.

examples are presented here to show how the same basic techniques may advantageously be used in articles differing markedly in subject matter.

The first example has been chosen for two reasons: it shows how a unit of exposition may be developed as a part of a longer paper, in this instance one which is partially persuasive; it shows how coherence may be obtained by the use of phrases and reference words (indicated by boldface in the example).

The controlling purpose of the entire article might be stated as showing the usefulness of scientific method in human affairs. The purpose of this part of the article is to explain the importance and use of measurement in scientific method. Nothing is included which does not contribute to this purpose.

The arrangement of paragraphs leads from the general to the specific. The first two paragraphs, developed partly by comparison and partly by example, support the author's opening generalization that the scientific method is a measuring method. The third paragraph divides measurement into qualitative and quantitative and also serves as a transition leading into the specific example to which the next two paragraphs are devoted. This example in turn is used to demonstrate the point with which the selection ends—the possibility of serious error if measurements are not accurately made and interpreted. This idea echoes the reference in the first paragraph to procedures which "look" scientific. The emphatic style of the short opening sentence and of the concluding sentence should be noted.

> . . . *The* **scientific method** *is a* **measuring** *method.* **It** is the **method** by which the "facts in the case" are weighed. **It** is the **method** which uses "facts" as the basis of judgments. Since **science** is based on **measurement,** any situation which can be treated by the use of units, methods and means of **measurement** has reached **its** highest possibility of development in the matter of **scientific** treatment. **Of course,** if the wrong units are used, and the **methods** and means used are not applicable to the situation, the whole procedure may *look* very **scientific,** but it is not. *The* **scientific method** *will not tolerate anything that is false,* whatever the intentions of those who try to use it.
>
> It should **also** be recognized **that** the **scientific method** may be applied to the phenomena of human behavior, **and that** the scientist is able to measure some kinds of human reactions. **But so far,** the kinds

of measurements which may be made in this field are for the most part *relative* and not absolute. A relative measurement is one which associates a given kind of behavior with a given kind of environment. It is not absolute in the sense of *how much.* For example, it is a well demonstrated fact that fear (for which there is no unit of quantitative measurement) will cause many specifically determinable body changes (some of which can be measured) and that the relationship between fear and these changes is always positive. Fear then is a *kind of force* which can be depended upon to produce specific *kinds* of reactions. . . .

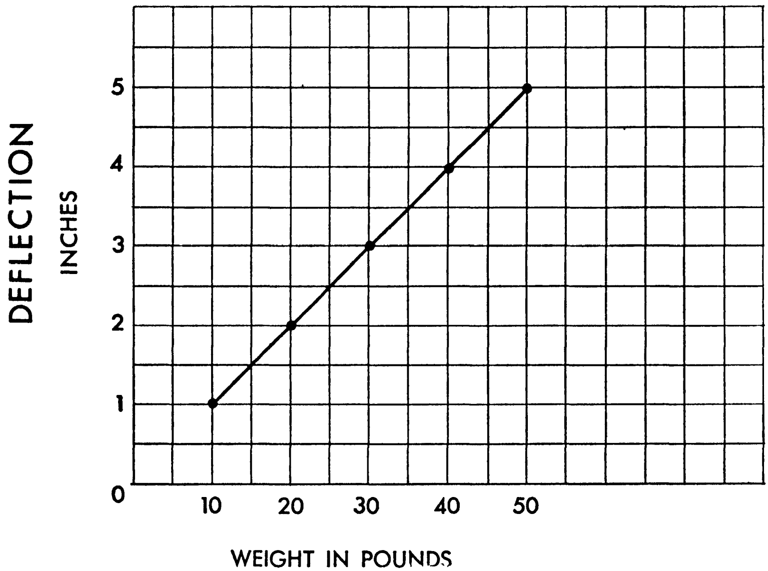
The scientist measures quantities (how much) and qualities (what kind) and the relationships between forces—that is, how one *tends* to behave with respect to the other. These tendencies may be measured *quantitatively* in some cases and only *qualitatively* in others. How does the scientist go about making such measurements? What are some of the methods he uses, especially in measuring trends and relationships?

A usual method employed for measuring relationships is that of charting observations. For example, suppose it is desired to know the relation between the amount of weight put on a given coiled spring and the corresponding amount of deflection in inches. The measurement is made by putting different known weights on the spring, observing the number of inches of deflection with each weight, and plotting the results. Such an experiment with a given spring may lead to the following observations:

When the weight in pounds is	*The deflection in inches is*
10	1
20	2
30	3
40	4
50	5

A piece of paper is ruled as shown in the accompanying figure, and each observation is plotted as follows: on the lower "scale," weight in pounds, locate the reading 10, then follow the line upward and make a mark on the horizontal line passing through the number 1 on the deflection "scale" to the left of the chart. Follow the same procedure for relating the weight 20 pounds to the deflection 2 inches, and so on. Connect the five points with a line. By this means the relationship between any load between 10 and 50 pounds and the resulting deflection in inches, can be predicted, for this spring or any

other spring made exactly like **it** in material and dimensions. **For example,** it can be stated that if the **load** should be 35 pounds, the **deflection** will be 3½ inches.



This prediction is made by locating the number 35 on the **weight** scale, tracing upward a **line** ··· and when the slanting **line** connecting the points is reached, tracing from there to the left a horizontal **line** ··· and reading the number (3½) which it meets on the **deflection** scale.

In using **the above** relationship to predict what **deflection** will result from a **given load,** you will note that the **load** (35) chosen for illustration was *between* 10 and 50 pounds. Can the chart be used to predict the **deflection** resulting when a **load** *greater* than 50 pounds is applied? Does the trend shown hold true *beyond* the range of observation? **It** may, and then again **it** may not. It depends on the length of the **spring,** for one thing, and on the range of **elasticity** of the material of which the **spring** is made. It is known from experience that a given **spring,** when stretched *beyond a certain amount,* will not **deflect** uniformly—**that is, equal** amounts for **equal** additional **weights. This** point can be **determined** by experiment, but the fact in **this** case is that it *was not* **determined. Hence** the behavior of the **spring** when loaded more than 50 pounds *cannot* be confidently **predicted** from the known facts. Any **prediction** in **this** matter would be a guess which **might** or **might** not give the correct answer.

> **This** is very important, for the **incorrect** use of **data** and the **incorrect** interpretation of the range over which a given observed relationship between the **data** holds, has led to some serious **errors** in **predicting** probable future events. . . .[18]

The second example is noteworthy for the way in which interest is maintained through effective arrangement of the facts with no sacrifice of conciseness. In approximately 750 words the author establishes the truth of his opening description of the rattlesnake's rattle as "one of the most remarkable structures in nature," and explains its structure and function. To emphasize the strong sense of paragraph value in the selection, marginal notes are included. An examination of the paragraph topics shows that though each paragraph is a unit, all contribute to the author's central purpose, giving unity to the article as a whole. The sequence of the paragraphs, ending with the discussion of the rattle's origin and purpose, indicates a feeling for climax. The article opens briskly and ends strongly. It would be difficult to accomplish more in the same number of words.

THE RATTLE[19]

"Remarkable" character of the rattle. The second and third sentences justify the use of the adjective.

The rattle is the most characteristic feature of the rattlesnakes, and is one of the most remarkable structures in nature. Nothing remotely resembling the rattle is found in any other group of snakes. The astonishment and incredulity with which early travelers to America were greeted when they returned to Europe with stories of a snake with a "bell" on its tail may easily be imagined.

Long interest in the subject. The historical aspects of the subject are not treated here, but a reference is given.

It is not surprising that so extraordinary a structure should have attracted the attention of naturalists from the time of its discovery. A long list of their writings on this subject is given by Klauber (Klauber, L. M., 1940, A Statistical Study of the Rattlesnakes. VII, The Rattle, *Occ. Papers San Diego Soc. Nat. Hist.*, No. 6, 62 pp., il.), who has also carefully reviewed the many theories regarding the rattle and studied its development, structure, and method of functioning.

[18] Walter Rautenstrauch, "The Scientific Method in Human Affairs," *The American Scholar,* 14:475-79, Autumn 1945.

[19] Karl P. Schmidt and D. Dwight Davis, *Field Book of Snakes*, New York, G. P. Putnam's Sons, 1941, pp. 290-93, courtesy G. P. Putnam's Sons.

Structure of the rattle. This paragraph is developed by details and comparison.

The rattle is made up of a number of segments that interlock loosely with one another to form a jointed string. The rattle is higher than it is wide, and is vibrated *sideways*, not up and down. Each segment is composed of a thin shell of hornlike substance, and the several segments striking against each other when the tail is vibrated produce the "rattling" sound. Actually the sound is more like the buzz of a cicada or the hiss of escaping steam than like a true rattling sound. Klauber found by using a kymograph (the instrument used to record heartbeats) that the rattle averages about 48 cycles per second, a speed that makes the rattle look blurred when it is in motion.

Development of the rattle. This account is adroitly introduced as a refutation of error.

One of the most persistent stories about rattlesnakes is that their age can be told by the number of segments or "joints" in the rattle. This story is false for several reasons. One reason is that a rattler adds a new segment to its string every time it sheds its skin, which it does three or four times a year or oftener, instead of only once. A rattlesnake is born with a delicate rounded structure, quite different from the true rattle in shape and texture, on the tip of its tail. This is the "pre-button," which is lost the first time the baby snake sheds its skin, usually within a week or two after birth. At the same shedding the snake acquires the "button," which is the first segment of the true rattle. Thereafter another segment is added each time the skin is shed, the button being displaced farther and farther from the tip of the tail. Of course, a young rattlesnake with only a button cannot rattle, since the button alone has nothing to rattle against.

Length of the rattle in nature. This paragraph assembles a number of facts of interest.

If a rattlesnake retained all the segments that were added to its rattle, in a few years it would be carrying around an enormous string of a dozen and a half or two dozen segments. Such phenomenal rattles are never seen in nature, although they are sometimes faked by slipping parts of several rattles together. A very long string does not rattle properly, and hence would be much less useful to the snake than a shorter one. Wild-caught rattlers usually have from five to nine segments in their strings, and one of 14 segments is exceptional.

What happens is that segments are continually lost from the end of the string through wear and breakage, so that an adult rattler with a "perfect string" (that is, with the original button present at the tip) is very unusual; most of them have "broken strings."

Function of the rattle. In this final paragraph of the article, which has been up to this point concrete in content, a philosophical point is introduced—the origin and function of a protective device in the snake. Thus, unlike the preceding selection, this one leads from the specific to the general.

The origin of the rattle is much easier to imagine when it is remembered that many harmless snakes vibrate their tails when they are nervous or angry, exactly as a rattler does. This is particularly characteristic of rat snakes and king snakes, for example. Many people have speculated on the purpose of the rattle, and it is now generally agreed that it is a warning to intruders who might injure the snake, like a skunk or badger intent on a meal or a bison that might crush the snake by stepping on it accidentally. It is all too easy to assume human purposive reasoning on the part of the snake, however, and hence to assume that it is consciously "warning" an intruder. Actually the snake vibrates its tail for the same reason that a harmless snake does—because it is nervous and angry; the fact that a startling noise results is incidental, and certainly unknown to the snake. Remember that a rattlesnake is deaf, and consequently cannot hear its own rattle!

The concluding example is strictly factual. Its readability derives from the clear arrangement of the facts. The opening paragraph follows the journalistic principle of giving the most important information in the "lead." The remaining paragraphs deal with different functional aspects of the building.

The American Memorial Library now under construction in West Berlin was made possible by the Point IV program of the United States Government; in the words of former U. S. High Commissioner John McCloy, it was given to the German city "in recognition of the courageous attitude of all Berliners during the time of the blockade." It will be one of the city's most important public libraries, serving as a research center and lending agency for some 60 smaller district libraries.

The new building is in the south central portion of Berlin, almost facing the present boundary between the eastern and western zones. Its main façade, an impressive curve of reinforced concrete, is to the

north, fronting on a square which is an important intersection for city transportation systems. The area to the south is densely populated, and contains numerous small and medium-sized industries.

Although part of the building is six stories in height, all reading rooms and public areas are on the ground floor, eliminating the need for public stairs or elevators. One lobby serves both the library and the 350-seat auditorium forming the low east wing; since checkrooms and washrooms are at the eastern end of the lobby, both are accessible from the auditorium even when the library itself is closed.

The plan of the main library floor stresses maximum flexibility. There are only two fixed partitions in the entire area—glass walls enclosing the children's department and the listening booths of the music departments; all other partitions are movable book shelves arranged around book lifts to the basement stacks. The book lifts are spaced at regular intervals along the entire length of the building, giving every department direct access to the stacks no matter how the movable partitions are placed. A long corridor, with display cases on both sides, runs from east to west, connecting every department with the lobby.

The location of the various reading rooms and departments has been worked out on a basis of use and noise. Those departments expected to be used most frequently are nearest to the main entrance, with the public catalog and reference room serving as a focal point. The "noisy" rooms—home reading, youth department, and children's library—will be at the eastern end of the building, the quieter specialized sections such as law and science at the opposite end.

Main floor book shelves will accommodate about 65,000 reference and general circulation volumes; the basement stacks will house another 360,000.[20]

Writers no doubt differ greatly in the conscious thought which they give to technique. Nevertheless, the theory of paragraph development and paper planning has its concrete counterpart in the work of successful writers of exposition. With an understanding of these basic techniques, the writer can advance confidently from short units of exposition to longer and more specialized types of papers.

STUDY SUGGESTIONS

1. Characterize each of the following passages as predominantly narrative, descriptive, persuasive, or expository:

[20] "American Memorial Library," *Architectural Record,* 113(3):125-26, March 1953.

"The seaweeds are primitive, water-dwelling plants, ranging from microscopic, one-celled forms to large and complex plants. They show an advance over some other groups of the thallophytes in the presence of the green coloring matter,—chlorophyl, which is, however, in certain of the algae masked by brown or red pigments. . . . Upon other structural and reproductive characters coupled with the difference in color is based the classification into green, brown, and red algae." [21]

". . . a young man sitting outside on a bench turned his head and greeted him by a careless nod. His face was rather long, sunburnt and smooth, with a slightly curved nose and a very well-shaped chin. He wore a dark blue naval jacket open on a white shirt and a black neckerchief tied in a slip-knot with long ends. White breeches and stockings and black shoes with steel buckles completed his costume. A brass-hilted sword in a black scabbard worn on a cross-belt was lying on the ground at his feet." [22]

"The most obvious thing about Ruskin is his sensibility. Other characteristics—his integrity, his simplicity, his attitude towards art, his fatherly affection for the English poor, his querulous indignation—are the most striking at certain times; but underlying all these and animating his whole life is an extreme emotional sensitiveness." [23]

"Having finished his pipe and obtained a bit of candle in a tin candlestick, Citizen Peyrol went heavily upstairs to rejoin his luggage. The crazy staircase shook and groaned under his feet as though he had been carrying a burden. The first thing he did was to close the shutters most carefully as though he had been afraid of a breath of night air. Next he bolted the door of the room." [24]

According to a newspaper account, so many agencies had reported directly to the President that the situation became a nightmare to experts on military and industrial organization. And it grew steadily worse as Congress added more to the list.

"Military theorists," it was noted, "say no top-level commander should have more than seven or eight subordinates directly under him. Management engineers have said that no policy-making official in industry should have to deal with more than four or five second-level men.

"But directly under the President of the United States are 61 agencies—departments, commissions, authorities, administrations, etc. Be-

[21] H. W. Shimer, *An Introduction to the Study of Fossils*, New York, The Macmillan Company, 1924, p. 35.

[22] Joseph Conrad, *The Rover*, London, E. P. Dent and Sons, 1926, p. 39.

[23] Walter S. Hinchman and Francis B. Gummere, *Lives of Great English Writers*, Boston, Houghton Mifflin Company, 1908, p. 447.

[24] Conrad, *op. cit.*, p. 11.

sides that there are a number of permanent committees and temporary commissions. More than 235 officials have direct access to him."

"The concrete highway was edged with a mat of tangled, broken, dry grass, and the grass heads were heavy with oat beards to catch on a dog's coat, and foxtails to tangle in a horse's fetlocks, and clover burrs to fasten in sheep's wool; sleeping life waiting to be spread and dispersed, every seed armed with an appliance of dispersal, twisting darts and parachutes for the wind, little spears and balls of tiny thorns, and all waiting for animals and for the wind, for a man's trouser cuff or the hem of a woman's skirt, all passive but armed with appliances of activity, still, but each possessed of the anlage of movement." [25]

2. Select one of the expository selections from Appendix A and analyze the structure and development of the individual paragraphs; point out the relationship of each paragraph to the plan of the selection.
3. Write two or three well-developed paragraphs, explaining the distinction between pure and applied science and using comparison, contrast, and illustration as the principal means of paragraph development.
4. Write a paragraph in which you state an opinion as a topic sentence and then present evidence in support of this opinion.
5. Write a paragraph in climax order, devoting the first part of the paragraph to controverting a belief which is in your opinion erroneous and concluding the paragraph with a topic sentence summarizing the proposition which you have undertaken to establish.
6. Examine a miscellany of short expository articles such as one might find in current scientific or industrial publications or in periodicals and state in a sentence what you understand to be the central purpose of each article.

[25] John Steinbeck, *The Grapes of Wrath*, New York, The Viking Press, 1939, p. 20.

CHAPTER 10 THE RESEARCH PAPER

I. Types of long scientific papers
   A. The report and the review
   B. The thesis
   C. The research paper
II. Preparation of a research paper
   A. Steps in writing
   B. Pervasive importance of the problem
   C. Value of the outline
   D. Clarity of framework
III. Process of evaluating a research paper
   A. Criteria employed
   B. Frequently occurring faults
IV. Analysis of a paper from a scientific journal

> *Such is the substance of my faith; and if I were to sum up my credo in a single word, it would be that proud motto of Fustel de Coulanges,* Quaero—*I seek to learn.* SAMUEL ELIOT MORISON, Faith of a Historian, The American Historical Review, January 1951.

I. TYPES OF LONG SCIENTIFIC PAPERS

When the student of scientific writing turns his attention to long scientific papers, he is likely to think first of the *research paper.* This type of paper involves the investigation of a problem through library research and the presentation of the results in a fully documented composition. The preparation of a research paper has great value for the student because it affords training in many of the techniques employed in writing and preparing for publication various advanced types of scientific papers, particularly the *report,* the *review,* and the *thesis.* Though these types of papers differ in the situations which occasion them, and in the source of the subject matter, they share a basic pattern. This pattern consists of the statement of the problem

or subject to be treated, an analysis of the findings, and the presentation of the conclusions reached.

A. The Report and the Review

Two basic types of papers in scientific writing are the *report* of a scientific investigation (see Chapters 11 and 12) and the *review*. An essential difference between the two lies in the origin of the subject matter. The *report* presents at first hand the research of the author or authors. Many scientific journals are devoted to the publication of such reports. The purpose of the *review*, not to be confused with the book review, is to summarize and to some extent to interpret the research which has been done on a problem over a period of time. The writer of a review draws his material not from his own research but from published reports of research on the subject.

Reviews represent an intermediate stage between original reports and books. When a new field of research is opened up, the first publications to appear on the subject are reports, followed shortly by reviews, and later by books. When a topic awakens immediate and general interest, the periods of time between these stages may be very short. Some journals, such as *Chemical Reviews* and *Biological Reviews*, have as their principal purpose the publication of reviews. Reviews also appear in numerous periodicals published by academic, professional, and industrial groups. The value of a review depends in part upon an exact delimitation of the time and subject covered. In some fields annual reviews are customary. Since about three-quarters of a million scientific and technical articles are published annually,[1] the importance of the review in enabling the research worker to keep up with his own and related fields is evident.

Both the report and the review are formal scientific papers. As such, they are fully documented, the report with the references which give the background of the problem, the review with the sources covered in the paper. Many informative magazine articles resemble the review since they are designed to give a factual and interpretive presentation of a single topic. Such articles, being intended for a

[1] E. Bright Wilson, Jr., *An Introduction to Scientific Research*, New York, McGraw-Hill Book Company, Inc., 1952, p. 10.

less restricted group of readers, are not documented and are less formal and usually less authoritative than the scientific review.

B. The Thesis

The *thesis,* also a fully documented formal paper, is particularly associated with the academic requirements for certain college and university degrees. Based on the candidate's research, the thesis typically follows the pattern of the statement of the problem, presentation of methods and results, analysis and interpretation of findings, and the summarizing of conclusions.

Departmental directions as to the form and arrangement of the thesis should be carefully followed. Style manuals (see Chapter 14) and manuals in thesis writing [2] are valuable adjuncts to the instructions of the department or institution concerned. Theses are frequently published as books or, especially in the sciences, as journal articles.

C. The Research Paper

The *research paper* as it is known in colleges and universities is designed partly to afford instruction in the techniques of such advanced types of papers as the report, the review, and the thesis. At the same time the demands of the research paper are kept within the limitations of the classroom situation. The writing of a research paper culminates a project customarily completed in an academic semester. It is usually not expected that the undergraduate should do original research or that he should cover library sources with the thoroughness of the professional reviewer. It is possible, however, for him to approach a problem from an individual angle, to collect and select material bearing on that problem, to analyze and interpret his material, to come to conclusions concerning his problem, and to present his work in a properly drawn up and adequately documented paper.

The term *research paper* has been the subject of some controversy. Since the word *research* strictly used denotes original investigation leading to new knowledge, some scientists have objected to the use of the word *research* in connection with undergraduate study, pre-

[2] A useful manual of this type is *Form and Style in Thesis Writing* by William Giles Campbell, Boston, Houghton Mifflin Company, 1954.

ferring to reserve it for work leading to advanced degrees and beyond. It has been suggested that in graduate research the emphasis falls on the *search*, implying a searching for new knowledge, while in undergraduate work the emphasis is on the *re* (again), implying that the student, from his own point of view, re-examines materials already known. Since the *research paper* even on the undergraduate level represents the working out of a problem (see Chapter 2), it is more challenging than the *reference paper*, which represents only the summarized presentation of source material on an assigned topic. The scientist's regard for the term *research* should, moreover, be respected. The tendency to refer to all library reference work as "doing research" is to be deplored.

It should be noted finally that some authoritative published papers which interpret previous research may be considered research papers rather than reviews since they represent a discussion of a single aspect of a subject rather than a review of it as a whole.

II. PREPARATION OF A RESEARCH PAPER

Most of the considerations which apply to writing a research paper apply also to writing other types of papers described in this chapter. For the sake of simplicity these considerations are discussed here in connection with the research paper, with the understanding that much of what is said has a broader application. The length of time devoted to the entire process of collecting, studying, and writing up material may range from the several months usually allowed for an undergraduate research paper to several years for a doctor's thesis or report of research.

A. Steps in Writing

Many of the steps involved in the writing of the research paper and closely related types of papers are an integral part of the philosophy and method of scientific writing. Consequently, the discussion in this chapter relies on the detailed treatment of these steps in other chapters of this book, as the following outline indicates.

1. Finding and limiting the problem (see Chapters 1 and 2)
2. Locating and selecting material and preparing a tentative bibliography (see Chapter 4)

3. Reading and taking notes (see Chapter 4)
4. Analyzing and interpreting material (see Chapters 5 and 6)
5. Preparing an outline (see Chapter 5)
6. Writing the paper (see Chapters 7, 8, and 9)
7. Documenting the paper (see Chapter 14)
8. Revising the paper (see Chapter 8)
9. Providing illustrations if needed (see Chapter 15)
10. Putting the manuscript into final form (see Chapter 14)

These steps are interrelated, and one step cannot necessarily be completed before another is begun. An early focusing of the problem will always save time in collecting material and preparing the outline. Nevertheless, the fuller understanding of the subject which the student gains through his reading may at times make it desirable to restate the problem midway in the study. Similarly, the finding of new material may necessitate a revision of the outline. Hence, like science itself, the plan for the preparation of a research paper should not be so inflexible that it precludes taking advantage of new facts or new ideas.

B. Pervasive Importance of the Problem

If the research paper is to rise above mere reference work, it must do so on the basis of the problem. Research training is held to be inadequate when it develops "scientific workers who know how to carry out instructions and to follow in the footsteps of others, but who have not learned how to discover a rewarding research problem, how to plan the attack on it and how to solve it." [3] The first task of a research paper is to explain the problem and its background to the reader, the second to give an account of the research, and the third to summarize the conclusions. Since all of these phases of the paper depend on the problem, the paper is likely to have progression and unity to the degree that the writer keeps the problem in the forefront of his mind.

Although the introductory section which states the problem and the concluding section which sums up the outcome appear respectively at the beginning and the end of the paper, their relationship is very close. If the problem has been well conceived, well investi-

[3] George B. Kistiakowsky, The New York *Times*, October 4, 1952, p. 19.

gated, and well stated, the point or points summed up in the conclusion will correspond to those under investigation as explained in the introduction.

An adequate introduction to a research paper must contain all the information necessary to an understanding of the problem. Points covered in a typical introduction include, not necessarily in this order:

1. *A brief account of the history of the problem.* This account serves to show the origin and significance of the problem and to relate the paper to previous studies.

2. *A definition of key terms.* All terms essential to the problem should be defined initially if there is any possibility that the terms will be ambiguous or confusing. Often technical papers do not require definitions, since specialists in the field are already familiar with the accepted terminology. (See Chapter 3.)

3. *A statement of the assumptions on which the investigation is based.* These assumptions may be implicit in the historical background of the problem and the definition of terms. It sometimes happens, however, that certain previous work has been accepted by some investigators in the field and not by others. In such situations the writer should make his own position clear.

4. *The simple statement of the problem.* The intention of the simple statement of the problem is to set forth explicitly for the reader the specific purpose of the study covered in the research paper. In papers intended for technical readers it is customary to make this statement directly. In papers intended for the general reader the problem may be stated less directly or expressed in the form of a question. However, the writer of a report of research, a review, or a thesis should not hesitate to tell in so many words the purpose of his paper.

It is a good plan for the writer at an early stage of his investigation to prepare a preliminary draft of his introduction, which later, when the study is nearly complete, is rewritten. The conclusion cannot, of course, be written until all the material has been examined and interpreted. The first of the examples given here, all of which are accompanied by explanatory notes, presents the introduction and conclusion of a social anthropologist's inquiry into the curious practice of water witching.

WATER WITCHING: AN INTERPRETATION OF A RITUAL PATTERN IN A RURAL AMERICAN COMMUNITY [4]

The opening sentence of the introduction is a direct statement of the specific problem of this paper. The remainder of the first paragraph relates this specific problem to previous discussions of water witching.

[1] This paper will attempt an interpretation of the phenomenon of water witching as a folk-ritual pattern which has been extraordinarily persistent in rural American culture and which has not been replaced by the services of competent ground water geologists in locating family-size wells in countless rural American communities. There is a vast literature on this water-divining pattern, but by and large the writings have centered on the problem of whether dowsing does or does not work as an empirical technique for locating underground supplies of water. The latest publication of note in this vein is the best seller by Kenneth Roberts, *Henry Gross and His Dowsing Rod*, which, as a spirited defense of the empirical validity of the dowsing technique, has renewed and publicized the age-old controversy. But, so far as this writer has been able to determine, there has been no systematic attempt to analyze the phenomenon as a folk-ritual pattern functionally equivalent to the magical practices found in the nonliterate cultures of the world.

The second and third paragraphs explain the historical background of the immediate problem—the significance of water witching—by relating it to the larger problem of the significance of rituals. The theory of ritual stated here is one of the concepts on which this study is based.

[2] Emanating from the writings of Pareto, Malinowski, and Weber, and continuing in the present generation of theorists—notably Parsons, Kluckhohn, and Homans—a general body of theory concerning the function of ritual in the situation of human action has emerged. Briefly stated, the essence of this theory is that when human beings are confronted with situations that are beyond empirical control and that are, therefore, anxiety-producing both in terms of emotional involvement and of a sense of cognitive frustration, they respond by developing and elaborating non-empirical ritual that has the function of relieving emotional anxiety and of making some sense of the situation on a cognitive level. Kroeber has recently

[4] Evon Z. Vogt, "Water Witching: An Interpretation of a Ritual Pattern in a Rural American Community," *Scientific Monthly*, 75:175-76, 186, September 1952.

questioned the universality of this relationship by pointing out that the Eskimos, who live in a far more uncertain and anxiety-producing environment than do Malinowski's Trobriand Islanders, have little ritual as compared to the Trobrianders, whereas given Malinowski's formulation one would expect more Eskimo ritual. Kroeber goes on to indicate that the arctic environment is so severe that had the Eskimos devoted much energy to the development of ritual patterns, they would long since have perished. This latter point is sound, but further analysis of Eskimo culture may reveal that, although there is little elaboration of ritual, the ritual patterns that do exist are still clustered around the greatest uncertainties of Eskimo life.

[3] Others, notably Radcliffe-Brown, have raised the issue as to whether rituals do not create anxiety (when they are not performed or are not performed properly) rather than alleviate it. Homans has treated this problem in terms of "primary" and "secondary" rituals focused around "primary" and "secondary" types of anxiety. Primary anxiety describes the sentiment men feel when they desire the accomplishment of certain results and do not possess the techniques that make these results certain; secondary anxiety describes the sentiment resulting when the traditional rites are not performed or are performed improperly. Kluckhohn has carried the analysis further by demonstrating that ritual patterns have both a "gain" and a "cost" from the point of view of the continued functioning of a society, and that problems are created as well as solved by the presence of ritual patterns in a given culture.

Paragraphs four and five advance the author's own theory of ritual patterns and set up his assumptions concerning the nature of ritual.

[4] Finally, I should like to advance the theory that ritual patterns which initially emerge as responses to critical areas of uncertainty in the situation of action are elaborated and reinterpreted in terms of certain selective value-orientations in a given culture.

[5] We are brought, then, to a dynamic conception of ritual which includes the following considerations: Ritual patterns develop as a response to emotional anxiety and cognitive frustration in a situation of uncertainty; but ritual

patterns come to have both "functional" and "dysfunctional" aspects (both a "gain" and a "cost") for the continuing existence of a society as the patterns are elaborated and developed in terms of the selective value-orientations of a given culture.

The last paragraph of this section states the three aspects of the problem with which the paper is concerned.

[6] In this paper I shall analyze the relationship of the water-witching pattern to the critical area of uncertainty in the location of underground water supplies, explore the functional and dysfunctional aspects of this pattern for the continuing survival of the community, and try to show how the pattern has become an expression of the value stress on "rational" environmental control in a rural American community. . . .

The two final paragraphs of the paper state and explain briefly the conclusion that the author has reached as the result of his study. The points brought out in the conclusion correspond to those raised in the introduction: the relationship of water witching as a ritual pattern to an area of uncertainty, the significance of this pattern to the community, and the attachment of value to the supposedly "rational" control of the environment.

[7] Our conclusion is that water witching is a ritual pattern which fills the gap between sound rational-technological techniques for coping with the ground water problem and the type of control which rural American farmers feel the need to achieve. The best geological knowledge of ground water resources that is currently available still leaves an area of uncertainty in the task of predicting the exact depth to water at a *given* location in a region with a variable ground water table. The water-witching pattern provides a reassuring mode of response in this uncertain situation.

[8] Thus, although water witching is to be regarded by the scientific observer as a nonempirical means for achieving empirical ends—and is functionally equivalent to the magical practices of nonliterate societies—it is generally viewed as a rational-technological procedure by its adherents in rural communities. The technique can, therefore, best be described as a type of "folk science" or "pseudo science" in the rural American cultural tradition. As a body of pseudo-scientific knowledge, the water-witching pattern in our rural farming culture is the same order of phenomena as the pseudo-scientific practices that cluster around situations of uncertainty in other areas of our culture; as, for example, in modern medical practice where there appears to be a pattern of "fashion change" in the use of certain drugs, an irrational "bias" in favor of active surgical intervention in doubtful

cases, and a general "optimistic bias" in favor of the soundness of ideas and efficacy of procedures which bolsters self-confidence in uncertain situations.

The next example of an introduction is of particular interest because of the definitions presented as a background for the remainder of the paper. (The figures referred to in the text are not included here.)

STRENGTH IN TENSION [5]

How tensile strength data from standard property tests can be used more effectively in design

The first two paragraphs explain the importance of tensile strength data and show the difficulties involved in interpreting tension strength values.

Actual loading of a machine part can seldom be resolved into simple unidirectional stresses. Consequently the prediction of actual part performance from theoretical loading considerations and knowledge of conventional strength "properties" data is at best an approximation. The margin for error, however, can be reduced by careful attention to the implications of the various strength properties.

Strength in tension is perhaps the most widely used type of strength data, being employed not only to supply numerical strength values, but also as a comparative indicator of strengths of various materials. Here again, caution is necessary, since compression, torsion, shear or flexural strength may actually be a better indicator for the particular design. Additionally, different materials are not always evaluated on the same basis—tension strength values reported for one material may not have the same meaning as similar values reported for another. Condition (cold-rolled, heat-treated, etc.) has a large influence on the value reported, as do section size, variations between lots and other effects.

Paragraph three states the immediate purpose of this paper.

Some of these considerations will be discussed in this article, along with a summary of the main tensile properties for representative engineering materials. Tensile strength and various other

[5] Robert L. Stedfeld, "Strength in Tension," *Machine Design*, 25(11):161, 163, November 1953.

strength properties of materials will also be considered further in future articles.

The next three paragraphs offer classifications and definitions which are essential to the reader's understanding of the remainder of the article.

Characteristic Stress-Strain Curves: As pointed out in many engineering texts, most materials can be classified into one of three groups: ductile, brittle or elastomeric, as shown in *Fig.* 1. A ductile material, *Fig.* 1 *a*, has a stress-strain curve composed essentially of an elastic portion, in which the stress-strain curve follows Hooke's law, and a "plastic" portion where the curve deviates from a constant stress-to-strain relationship. Some ductile materials, such as mild steel, have definite yield points. Most, however, show only a relatively sharp "bend" where the material enters the plastic region, without a definite reversal in slope of the stress-strain curve. The main distinguishing features of the curve are the large "hump" and the difference in strain or elongation between the tensile strength and breaking strength.

Brittle materials usually have a curve similar to *Fig.* 1 *b*. Generally, the distinction between brittle and ductile materials is the tensile strain at rupture; metals with a total elongation greater than 0.05-inch per inch (5 per cent elongation), for instance, are considered to be ductile. The curve of *Fig.* 1 *b*, however, may be representative of materials normally considered as brittle but which have larger elongations than called for by this criterion. For most materials with a curve of this shape, such as gray cast iron or austenitic alloy steels, there is no true elastic region; the elastic portion of the curve is slightly curved—and even for ductile materials there is some question whether highly accurate measurements might not show deviations from Hooke's law. The "tail" of the curve (roughly from the yield strength upward) may be shortened or missing entirely for very brittle materials. Laminated plastics, for instance, have almost no elongation, and consequently the stress-strain curve becomes practically a straight line.

Stress-strain curves for elastomeric or soft materials resemble *Fig.* 1 *c*. Soft rubber and plastics such as vinyl chloride, nylon and polyethylene are typical examples.

The third and most technical of the examples is the introduction and conclusion from a forty-five page contribution to *Chemical Reviews.* Following the conclusion, nine pages of the review are devoted to listing 378 references, ranging in date from 1861 to 1953 with a preponderance in the 1940's and 1950's. The selection is notable for the clarity and conciseness of its style.

THE NATURE OF THE MINERAL PHASE OF BONE [6]

I. Introduction

This review opens with an explanation of the composition of bone.

In nearly all of the higher forms of animal life, structural strength and rigidity are provided by the bony skeleton. The strength and rigidity of bone are derived from its composition and architecture, which is unique among living tissues. About one-third of its mass is in the form of mineral crystals, which are embedded in an extracellular matrix composed largely of a complex interwoven network of a tough fibrous protein, collagen. There is present also a poorly characterized interfibrillar "ground substance." Bone cells, attached to one another by protoplasmic processes, small blood vessels, and variable amounts of extracellular and intracellular fluid make up the rest of the organic matrix.

The next two paragraphs state the problem and purpose of the paper and define its coverage.

This review is concerned with the general problem of establishing the chemical nature and properties of the mineral crystals of bone. While this problem has been under investigation for over a century, very recently a number of new techniques, principally electron microscopy and tracer chemistry, have added a great deal to our understanding. With this newer knowledge an attempt has been made to present a unified concept of the problem. To do this it has been necessary, where critical data are lacking, to resort to speculation. It is the aim of this review to stimulate interest and research, not to predict the future. If, as new facts are learned, *all* of the speculation here pre-

[6] W. F. Neuman and M. W. Neuman, "The Nature of the Mineral Phase of Bone," *Chemical Reviews,* 53(1):1-2, 35-36, August 1953.

sented proves false, the authors will be neither surprised nor discouraged.

Only certain phases of the subjects have been covered in detail. The reader is referred, therefore, to a number of excellent reviews (9, 65, 80, 81, 121, 139, 187, 241, 248, 262, 291, 325) for a more comprehensive bibliography. . . .

VIII. Conclusions

The seven paragraphs which comprise the conclusions of this review proceed from the more specific conclusions to those which are more theoretical and speculative. In accordance with the problem as stated in the Introduction, the conclusions are concerned with "the chemical nature and properties of the mineral crystals of bone."

Subject to modification and, with the risk of oversimplification, the present knowledge concerning the nature of the mineral phase of bone may be summarized as follows:

The crystals of bone are minute tablets, 25-50 Å. thick, approximately 400 Å. long and nearly as wide. In the intact bone, these crystals are found to be closely associated with the collagen, lying between the characteristic banding of the fibers, with the long crystal axis (and the *c*-axis) parallel to the longitudinal direction of the fiber.

These crystals are comprised of calcium, phosphate, and hydroxyl ions arranged in a hexagonal lattice structure which diffracts x-rays to give a pattern characteristic of the apatite minerals. This lattice structure is not of fixed composition but may undergo some isomorphic substitution, particularly at the surface.

The specific surface area of bone mineral is enormous, because of the minute size of the crystals. To obtain measurements it is necessary to remove the organic material by heat treatment; therefore, the observed values of about 100 $m.^2/g.$ are minimal.

Because of this enormous area, surface phenomena dominate the chemical behavior of the bone mineral. One of the most important processes yet demonstrated is ionic exchange. The surface ions have been shown to be in equilibrium with the solution bathing the crystals. By heteroionic exchange, many non-lattice ions are bound by the crystals: hydronium, sodium, fluoride, carbon dioxide, and citrate. The crystals become highly hydrated in aqueous medium because of a

boundary charge and the presence of exchangeable ions. The extreme thinness of the crystals permits an interchange of ions within the crystal with ions in solution, a process termed recrystallization.

The variability of the lattice structure, and the crystal surfaces especially, does not permit the application of the usual solubility principles. No single K_{sp} governs the solubility of either bone crystals or the basic calcium phosphates. However, the K_{sp} of $CaHPO_4$ sets a solubility maximum, above which precipitation occurs. Present data indicate that calcification *in vivo* involves a catalyzed crystallization rather than a precipitation, as frequently postulated.

All evidence is consistent with the belief that the skeleton and the body fluids are in equilibrium. The bones do not regulate the blood levels but they may provide considerable buffering action with respect to [Ca^{++}], [HPO_4^{--}], and [H_3O^+]. Thus, changes in blood composition induced by diet are reflected by the skeleton, especially in acidosis. The deposition of radioisotopes confirms the dynamic equilibrium between blood and bone. Furthermore, recent studies with isotopes have shown dramatic variations in reactivity from bone to bone and from one microscopic area to another within a given bone. These data point up the fact that the crystal surfaces become less and less reactive with increasing age of the crystals. Foreign elements that concentrate in the skeleton do so by one of two processes: (*1*) a surface exchange with ions in the mineral crystals or (*2*) a specific but uncharacterized deposition in the organic or osteoid portion.

C. Value of the Outline

Early in the stages of collecting material and taking notes on the problem under investigation, the writer of a research paper begins to consider the analytical divisions of his subject matter and the preparation of an outline. (See Chapter 5.) The final draft of the outline of the paper becomes a basis for the table of contents, if one

is desired. (See Chapter 14.) During the actual preparation of the paper, however, the outline is useful primarily as a plan for its composition. To serve this purpose the outline must represent both a logical organization of the material and a workable guide to its presentation.

The Introduction and the Conclusion are fixed points at the beginning and end of the outline. Usage differs as to whether the Introduction and Conclusion should be treated as outline topics and given Roman numerals or should appear at the beginning and end of the outline perhaps italicized but without numerals. Either practice is correct, so long as the Introduction and Conclusion are treated alike. It is not desirable to co-ordinate the Introduction and Conclusion with a middle section, the "Body." Although this arrangement may seem superficially logical, it does not represent accurately the relationship between the analytical divisions of the paper. In an outline for a relatively short paper the Introduction and Conclusion are often omitted, and the central idea of the paper is expressed in a theme or thesis statement preceding the outline proper.

The preparation of the outline begins with the grouping of the note cards accumulated in the course of the investigation. (See Chapter 4.) The note cards should first be grouped under the main topics suggested by the headings on the cards, and then the question of subdivisions should be considered. At this stage a logical sequence of ideas and a valid distinction between major and minor topics are more important than the outward form of the outline. When the writer is ready to consider the final form of his outline, he may choose between two types—the *topic outline* and the *sentence outline.* The topic outline has the advantage of being more easily converted to a table of contents, the sentence outline of showing more fully the subject matter and process of reasoning developed in the paper.

In a *topic outline* the main topics are usually made up of short phrases, most frequently nouns and their modifiers. The subtopics show a greater variety of grammatical structure, including prepositional phrases, infinitives, and even dependent clauses. Neither the main topics nor the subtopics in a topic outline are ever complete sentences.

In the following topic outline, set up by a student in preparation

for writing an undergraduate research paper, a theme statement replaces the introduction and conclusion.

AN INQUIRY INTO TEMPER TANTRUMS

Statement of theme: Temper tantrums are basically reactions to frustration which may often be effectively treated by redirecting the child's energy.

I. The temper tantrum as a response to frustration
    A. The immediate causes of temper tantrums
        1. Outside objects or persons
        2. Conflicts within the child himself
    B. Tensional outlets characteristic of different ages
II. The relationship of aggressive tendencies to environmental factors
    A. Importance of deficiencies in family situations
        1. Undesirable parental attitudes
            a. Excessive dominance
            b. Submission of the parent's will to the child's
        2. Poor sibling relationships
    B. The school as an influence in the child's behavior
        1. Possibility of transference of attitudes toward parents to the teacher
        2. Opportunity for development of social compatibility
III. The treatment of temper tantrums through a knowledge of the causes
    A. Ineffective forms of punishment
        1. Futility of verbal punishment
        2. Danger that physical punishment may lead to a feeling of insecurity in the child
    B. Effective forms of treatment
        1. Adapting treatment to the individual case
        2. Ignoring temper tantrums in very young children
        3. Redirecting energy
            a. Through reasoning
            b. By providing new outlets

In the *sentence outline* each topic and subtopic is stated as a complete sentence. The following outline covers much the same subject matter as the preceding outline, but the Introduction and the Conclusion are made separate topics and given Roman numerals.

AN INQUIRY INTO TEMPER TANTRUMS

I. Introduction
   A. Temper tantrums constitute a problem of frequent occurrence at home and at school.
   B. The temper tantrum may be considered basically a reaction to frustration.

II. The causes of temper tantrums are complex.
   A. Temper tantrums may be related to outside objects or persons.
   B. Temper tantrums may arise from conflicts within the child himself.
   C. Differing tensional outlets for frustration are characteristic of different ages.

III. Aggressive tendencies are related to environmental factors.
   A. Deficiencies in family situations are significant.
      1. Parental attitudes may be imitated or revolted against.
         a. The dominant parent exercises excessive control over the thoughts and actions of the child.
         b. The submissive parent allows the child too much freedom.
      2. Good sibling relationships are difficult to achieve but with great effort can be realized.
   B. The school shares with the home the responsibility for the child's behavior.
      1. Attitudes toward parents or other relatives may be transferred to the teacher.
      2. The school offers an opportunity to develop social compatibility.

IV. Effective treatment of temper tantrums depends upon a knowledge of their causes.
   A. Treatment should be adapted to the individual case.
   B. Certain types of punishment are ineffective.
      1. Verbal punishment is usually futile.
      2. Physical punishment may lead to a feeling of insecurity in the child.
   C. Temper tantrums in very young children may sometimes be ignored with good results.
   D. Temper tantrums may be treated by redirecting the child's energy.

V. Conclusion
   A. An understanding of temper tantrums may be achieved from a study of the environmental situation in the individual case.

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B.  Since temper tantrums are basically a reac-
    tion to frustration, they are in general
    best controlled by redirecting the child's
    energy.
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Certain conventions should be observed in preparing any type of formal outline. These conventions, illustrated by the foregoing outlines and by the revised outline in Chapter 5, may be summed up as follows:

1. The title of the outline is the same as the title of the theme.
2. The first word only of each topic is capitalized; the topic is not treated as a title. The topics should not depend for clarity upon pronominal reference to words in the title of the outline.
3. Indentation should be employed to show the subordination of the various ranks of subtopics.
4. Periods are used following the numerals and letters designating the topics. No periods are used following the topics in a topic outline. The usual sentence punctuation is used in a sentence outline.
5. The use of single subtopics under a heading should be avoided since a whole cannot logically be divided into less than two parts.
6. Co-ordinate headings should not be used to represent topics differing greatly in consequence.
7. Co-ordinate headings should be expressed in parallel grammatical structure.
8. Fewer than three or an excessively large number of main topics should be avoided as indicative of an inadequate analysis of the subject.

D. Clarity of Framework

One obligation of the writer of the long formal paper is to make the analytical framework of the paper evident to the reader. This end is accomplished partly by the use of centered or marginal headings in the text of the paper and partly by transitional words, phrases, and statements. The more definitely a paper is directed to a specialized group of readers, the more explicit and conspicuous the verbal indication of its structural divisions may be.

Writers of long formal papers are frequently hampered by attempting to follow advice which is particularly relevant to the short informal paper. The frequently heard admonition "don't write an introduction—just begin," while sound enough counsel when applied to some short papers, is inapplicable to the long formal paper. The space devoted to establishing the structural divisions of a paper should be proportional to the length and seriousness of the study.

In making clear the progress of thought between the introduction and the conclusion, transitional words, phrases, and sentences serve as "guideposts" to the reader. Such guideposts may point forward, awakening interest in what is to follow, or backward, reminding the reader of what has been covered. An enumeration early in the paper of the main points to be covered contributes to clarity and at the same time arouses some degree of anticipation in the reader. The following example, chosen from an article suggesting investigation into "some unsolved problems of the scientific career," shows the use of such an enumeration.

> These investigations would throw light on such problems as: (*a*) the special stresses, both economic and psychological, which occur in the life of the young scientist; (*b*) the great variety of conscious and unconscious forces whose interplay determines a young man's choice of scientific research as a career; (*c*) the interplay of conscious and unconscious forces in his subsequent emotional and scientific maturation; (*d*) how the special stresses which develop later in life react upon the earlier emotional forces which originally turned him towards science; (*e*) how unconscious stresses influence the young investigator's general approach to scientific research and scientific controversy; (*f*) how the unconscious symbolic significance of particular scientific problems and theories can distort the logic and the judgment even of men of exceptional ability. This article will attempt only to illustrate the wide variety of problems which are relevant to these general headings.[7]

Various transitional devices are used in the next selection, which opens with the last paragraph of the introductory section of the article. First, a transition is effected between the introduction and the next main division; then the idea of "an office without duties" is picked up at the beginning of the succeeding paragraph to keep the

[7] Lawrence S. Kubie, "Some Unsolved Problems of the Scientific Career," *American Scientist*, 41:597, October 1953.

point under discussion in the foreground of the reader's mind. The italics (except for those marking *esse* and *posse*) have been added to indicate words and phrases used with transitional effect.

> The issue is clear. In order to resolve it *let us begin* by examining the fundamental difficulty of the vice presidency: the enormous disparity between the importance of the office and the importance of the officer.
>
> *The first thing to observe* about the office is that it has no duties. *True,* the vice president is President of the Senate and, as such, performs duties analogous to those of the Speaker of the House. *But* the two offices are separate and distinct. "I am possessed," said John Adams, "of two powers; the one in *esse* and the other in *posse.* I am Vice President. In this I am nothing, but I may be everything. But I am President also of the Senate." The combination of offices has excited surprise. Roger Sherman explained it in the Federal Convention: "If the Vice President were not to be President of the Senate, he would be without employment."
>
> *Now an office without duties,* no matter how great its reversionary prospects, is not an office to inspire or satisfy the expectations of an ambitious mind. John Adams declared the vice presidency the most insignificant office that ever the invention of man contrived or his imagination conceived—almost the only one in the world in which patience and firmness are useless.[8]

In an effort to achieve smooth transition, inexperienced writers sometimes introduce cumbersome, roundabout explanations which impede rather than further the progress of thought. Illustrations of such ill-advised attempts at transition are shown here accompanied by suggested revisions.

Original	*Revision*
In the year 1944 the United States mined approximately 280,000 tons of ilmenite and 7,000 tons of rutile. Perhaps a few words should be mentioned about the ore of rutile. The ore of rutile comes from the state of Virginia.	In 1944 approximately 280,000 tons of ilmenite and 7,000 tons of rutile were mined in the United States. The ore of rutile comes from Virginia.
As indicated above, titanium is the fourth most abundant structural metal in the earth's crust, yet it	Though titanium is the fourth most abundant metal in the earth's crust, it was selling for $3,000 a

[8] Lucius Wilmerding, Jr., "The Vice Presidency," *Political Science Quarterly,* 68:19, March 1953.

was selling for $3,000 a pound only five years ago. What does this indicate? As you know, the cost of a product depends on the availability of the ore. If the ore is easy to extract from the earth or its bonding agent then the ore is relatively cheap. But if the ore is hard to extract from its bonding agent, we then have a very costly raw material. Thus we see the reason for the exorbitant cost of this metal. However, in the year 1946 the Bureau of Mines released a process developed by William J. Kroll, bureau consultant, for extracting titanium from its ore for the first time in practical amounts.

pound only five years ago. This high price, which accounts for the relatively small use of titanium, was due to the high cost of extracting titanium from its ore. In 1946 the Bureau of Mines released a process developed by William J. Kroll, bureau consultant, for extracting titanium from its ore for the first time in practical amounts.

In sum, transitional expressions, even in a formal paper, should not seem artificial or extraneous but should arise naturally out of thought relationships. In a long but less formal paper directed to the general reader, the analytical framework is present but is less apparent. Examples, anecdotes, analogies, and other means of holding the reader's interest are relatively prominent and tend to soften though not to obliterate the lines of the framework.

III. PROCESS OF EVALUATING A RESEARCH PAPER

When the research paper has been written, revised, and put into final form, it will presumably undergo appraisal. It will be helpful to the student if he can, while completing his paper, be aware in advance of the criteria by which it will be judged. Since the subjective element in a research paper as compared with that in impressionistic or purely creative writing is relatively small, it is possible to achieve some accord as to what should be expected in a research paper.

A. Criteria Employed

The research paper will ultimately, of course, be judged as a whole since the many factors which affect its quality are interrelated and combine to produce the impact of the entire paper. The principal

criteria employed in making an analytical appraisal on which this final judgment may be based are indicated here.

I. Research
   Focusing of problem—Coverage of sources—Evaluation of sources—Extent of reading—Efficiency of note-taking—Accuracy of documentation
II. Content of paper
   Selection of material—Interpretation of material—Individual contribution of ideas
III. Organization of paper
   Suitability of title—Outline—Introduction—Structural development—Transitions—Conclusion
IV. Composition
   Paragraph development—Sentence structure—Spelling—Punctuation—Usage
V. Style
   Conciseness—Effectiveness (Choice of words—Handling of sentences)—Readability
VI. Format
   Title page—Table of contents—Text of paper with headings indicating subdivisions—Presentation of references. (Some instructors may also require a letter of transmittal and/or an appendix, both of which are discussed in Chapters 11 and 12.)

B. Frequently Occurring Faults

Even when the student is aware of the criteria by which a paper is to be judged, he may fall short in meeting these standards through lack of experience. Faults which are often conspicuous in the finished research paper can best be prevented through an understanding of the causes which lead to them.

The poorly integrated research paper is a type all too frequently encountered. Such a paper consists of a piecing together of large blocks of material from a limited number of sources. This lack of integration results not so much from insufficient reading as from inadequate assimilation of material and a failure to relate the findings to the problem under consideration.

Lack of balance is another common fault in research papers. Disproportionate space is given to relatively minor topics while important points are treated sketchily. This difficulty is attributable to

a number of causes, the principal ones being a faulty work schedule which leaves insufficient time for proper development of parts of the paper, a poorly constructed outline which fails to show relative values accurately, and disregard of a balanced outline during the actual writing of the paper.

The research paper which does not convey its central point to the reader fails in its purpose. This ineffectiveness in a paper may likewise be due to more than one cause. If the writer has not grasped the meaning of his problem, the paper will not progress logically from the statement of the problem to its resolution and will lack the dynamic quality which readers find convincing. Again the writer may have worked out his problem but may not demonstrate its resolution because he does not appreciate the value of factual evidence and offers it in insufficient quantity.

Finally, the slipshod or generally careless paper is ubiquitous. Such a paper, with its irregular margins, poor handwriting or numerous typographical errors, inconsistent punctuation of documentary references, and many mistakes in spelling, merits little consideration. Faults of this sort in a research paper, moreover, suggest carelessness in such fundamental matters as accuracy of research and fidelity to sources.

IV. ANALYSIS OF A PAPER FROM A SCIENTIFIC JOURNAL

The theoretical study of the preparation of long scientific papers should be followed by a careful analysis of at least one paper which may be regarded as a model. Such a paper is presented here with the addition of notes pointing out features particularly pertinent to the needs of the student of scientific writing.

The title is specific, referring explicitly to the problem under consideration

THE UNEXPLAINED DIRECTION SENSE OF VERTEBRATES[9]

The opening paragraph, with its use of a variety of illustrations, is designed to capture the interest of the reader and comes to a climax with the concluding words "one of the unsolved mysteries."

The golden plover (*Pluvialis*) each fall flies a nonstop 2000 miles across the trackless Pacific from Alaska to Hawaii. The salmon (*Oncorhynchus*) returns from mid-ocean to spawn in the very stream in which it was born. A pet dog returns home over hundreds of miles of unfamiliar

[9] William J. Beecher, "The Unexplained Direction Sense of Vertebrates," *The Scientific Monthly*, 75:19-25, July 1952.

terrain. We are in danger of thinking of the "direction sense" here exhibited as commonplace because these events occur every day. But actually it is one of the unsolved mysteries.

The two succeeding paragraphs continue the statement of the problem by illustrating the direction sense of vertebrates by reference to the migration of birds.

Take birds, for example. If these mobile vertebrates were to survive as a type, the early models must have been able, despite stormy winds and extensive wandering in search of food, to return home to the care of young. Moreover, annual migrations may have been a necessity from the start. On a planet whose spin axis is inclined to the plane of rotation, there must always have been seasons, even sixty million years ago when Greenland was subtropical. These migrations probably became longer as the Tertiary unfolded and cooler climate crowded subtropical and tropical zones toward the equator, and the Ice Age saw birds pushed into our Gulf States and into Central and South America. Warm interglacial periods permitted long migrations, relieving the resulting population pressure, and finally the Ice Cap shriveled to the brooding relict we see in Greenland now. Today, waterfowl and other birds, following the long retreat of the ice, nest as far north as the short summer will permit successful raising of a brood.

What is the stimulus? We know now that it is not the warming weather but the increasing day length that conditions the northward migration of birds in spring and the growth of their reproductive organs (1). Each species may "set its clock" by the day-length threshold that will time its arrival on the nesting ground as soon as it is ready for occupancy—a vital matter for short-season nesters beyond the Arctic Circle. And it is not simply the cooling weather that sends birds south in the fall, for some leave us in July and August. This was necessary in the Ice Age, and the day-length threshold triggering southward movement then may be still in effect, since natural selection imposes no penalty for early migration south so long as a brood is raised. Wolfson covers the physiological basis of bird migration admirably (2).

This paragraph focuses the problem specifically on the precision of bird migration and the implication of an inherited direction sense.

What concerns us is the precision of these migrations. Many of these birds will return thousands of miles, flying through dark nights when they cannot see, to the particular thicket or meadow in which they nested last year. Moreover, the young in some species precede their parents in the southward migration to the wintering grounds, a journey they have never made before! This seems to imply inheritance of an instinctive direction sense, and such navigational ability may fall into the same class with the homing of pigeons or of swallows, used in war by the ancient Romans (3). All that has been said of birds goes for bats and many other mammals (particularly aquatic ones), various fishes, and in lesser degree reptiles and amphibians.

Here the theories which have been advanced to account for the direction sense of birds are reviewed and the coverage of the paper is indicated in the last two sentences of the paragraph, thus concluding the introduction or statement of the problem.

Historically, the semicircular canals seem to be the first sense organs credited with space-orientation, de Cyon suggesting them simply because the three, fluid-filled, sensory canals on each side of the head lie mutually perpendicular in the three dimensions of space (4). By 1882 Viguier had proposed that birds might be able to detect the earth's magnetic field in the canals (5), and by 1894 Hodge was claiming that pigeons home by random search (6). All these viewpoints have been pursued intermittently down to the present without resolving the question. This is particularly interesting because each of these theories has been revived by modern workers employing relatively refined investigation techniques within the past few years. Their evidence and conclusions are reviewed below.

Griffin's Theory of Random Search

This section of the paper is devoted to reviewing experiments concerned with "random search." The writer's comments on the facts given should be noted.

Griffin (7) believes that homing can be accounted for on the assumption that birds make a random search upon release until they chance to sight terrain familiar to them. Griffin and Hock (8) removed gannets from their nests on Bonaventure Island in the Gulf of St. Lawrence and released them 218 miles away at Caribou, Maine—70 miles from any coast. When followed by air-

plane these birds appeared to wander randomly until the St. Lawrence River or the coast was sighted, after which most returned home. The homing sense in these seabirds might not be expected to be highly perfected, since they are virtually never out of touch with coasts, and it is difficult to accept the application of these conclusions to all birds. Airplane observations of homing pigeons by Hitchcock suggest that a clear course toward the loft is taken (9). It is hard to account for most homing by chance. Watson and Lashley reported noddy terns (*Anous*) returning to their nests on Bird Key, Florida, from Galveston, Texas (north of their range), a distance of 460 miles across the Gulf against heavy winds in three days (10). Lack and Lockley report the record for wild bird homing in a Manx shearwater (*Puffinus*), transported from the coast of Scotland outside its range to Venice, Italy (11). It returned the 3700 miles in fourteen days, *averaging 260 miles per day!* When it is remembered that in both cases the birds would have to rest at night and feed on the way, even a thirteen-hour flying day seems excessive, yet this gives an average speed for the shearwater of 20 miles per hour.

Yeagley's Theory of Homing by a Coriolis-Magnetic Grid

In this section experiments designed by another investigator to test his theory of bird migration are described and discussed.

Yeagley hit upon the ingenious idea that pigeons may home by detecting the effect, due to their movement through the air, of the earth's magnetic field and of the Coriolis force caused by the earth's rotation (12). Lines representing equal intensity of these forces form a gridwork, those of Coriolis force being true latitude lines, those of magnetic force dipping down so as to intersect the latter at two points in North America. The essential fact is that the intersection at Pennsylvania State College is duplicated by a conjugate point at Kearney, Nebraska. Yeagley trained pigeons to home up to 70 miles to a mobile loft at State College, then transported them, with the lofts, to the vicinity of Kearney. He theorized that, if pigeons correlate their ground speed with these two forces to return

to the loft where they effect the right "feeling," then the birds should experience the same feeling at Kearney and should return there if released in its vicinity. Three groups of birds were released—one near Kearney, one near State College, and one midway between.

Although the last group were in a "tangential" area of parallel grid lines, where navigation should be impossible by Yeagley's theory, homing was easterly. This agrees better with a simple Coriolis theory than with magnetic field or grid detection. In fact, Thorpe (13) suggests that there seemed to be a tendency to home to the correct latitude. Yeagley believes the total flight vectors in these three groups support his theory, but this does not appear to be the consensus. The superimposing of a pulsating field (to destroy the effect of the earth's magnetic field) was effected by attaching magnets to the wings of pigeons, but this apparently did not affect their performance when compared with controls. Other experiments of this sort have always been negative. This valuable work is hard to assess because of terrain and meteorological differences between Pennsylvania's mountains and Nebraska's prairies. There is also a suspicion that homing ability has been "domesticated out" in pigeons. Although Yeagley is continuing his experiments with wild ducks, these are mainly diurnal and may migrate by visual clues. One would like to see the many nocturnal migrants tested for homing ability, as was done with swallows (*Hirundo*) by Polish investigators (14).

Ising's Theory of Coriolis Force Detection in the Semicircular Canals

A third theory is dealt with here and analyzed and commented on in some detail.

Ising thinks birds find their way by detecting the Coriolis force due to the earth's rotation (15). Any object on the equator has a momentum of about 1000 miles per hour (the earth's velocity at the equator), whereas objects at the North Pole have a momentum of zero. An object projected through the air at the North Pole from the equator will curve to the right because it is progressively moving into latitudes of lesser momentum. The

force it would have to overcome to fly to the pole is Coriolis force. Ising showed that a microscopic streaming occurs in a fluid-filled glass tube fashioned into a ring when it is rotated on its own diameter. This hydromotor force, which is due to Coriolis effect, obeys the same law as induced emf in a closed conductor, and Ising suggests that the direction sense of birds may be based on the motion, relative to the rest of the bird's body, of the fluid in the semicircular canals. The three canals of the inner ear are mutually perpendicular and thus are oriented in the three dimensions of space on either side of the head. Within the bony canals are membranous canals filled with endolymph, each one terminating in an ampulla containing a crista in which sensory hairs enveloped by a gelatin cupula or door record flow of endolymph. This is an inertia system, and the normal function of the canals is based on the inertia of this fluid. When an animal swings its head, the endolymph of the canal in the plane of the movement remains behind. Relative to the cupula it flows in the opposite direction, its velocity and amplitude directly proportional to the head movement. Ising reasoned that in such a system there should be an inertia effect resulting from the attempt to fly a true course despite the deviating influence of Coriolis force. His critics (16, 17) object that the effect is too small for the sensory apparatus to detect (about the amplitude of Brownian energy), but if the bird turns its head from side to side more rapidly, especially in flight, the force would increase considerably.

It has appeared to me that the semicircular canals may be more than a latitude sense, measuring the increasing value of Coriolis force northward (18). They should serve as a "gyrocompass," since Ising measured different values for different compass directions of the couple on the glass ring. But it also follows from Lowenstein and Sand's (19) finding that the ampulla in the living semicircular canal discharges spontaneously and that any rotation of the animal producing flow in a canal toward its ampulla enhances the discharge,

whereas flow away from it inhibits the discharge. Thus, if we visualize Coriolis force acting from west to east on the latitude lines there should be a streaming in the four vertical canals for a northward course which is inhibiting (−) in the ampullae on the left side, enhancing (+) in the canals of the right side. On a northwest course all the streaming will take place in a single canal of each side, since the other vertical canal will be at right angles to a force acting from the west. Although it must not be imagined that Coriolis force acts so simply, there seems to be a basis for thinking that the opposing sign of the canals of the two sides affords a means by which the resolution of the force for any latitude among the six ampullae will be different for each compass direction.

The maculae of the utricle, saccule, and lagena of the inner ear—each a layer of calcium carbonate crystals (30μ) embedded in gelatin on a mat of sensory hairs—form a gravity system similarly opposite in sign for the two sides. This may also aid direction-finding in the canals by measuring the deviation from the pull of gravity resulting from Coriolis force. In their normal functions the roles of the canals and maculae are supplementary, even complementary, the latter reporting deviations of the head from the horizontal by the effect of slight weight shifts of the crystals on the sensory hairs.

If this analysis is correct in principle, the canals and maculae may balance the Coriolis force value of a particular latitude differently for each direction—with the qualification that directions of 180° different will produce the same sensation. This provides a theoretical basis for the inheritance of a direction sense that would permit young birds to migrate south before their parents and for local populations of a species to pass on genetically the *exact* direction taken to breeding and resting grounds. The force, of course, increases on a northward course, decreases on a southward one. Thus young European storks (*Ciconia*) precede the parents to the wintering grounds in South Africa.

West German storks migrate southwest through France and Spain to Africa by way of Gibraltar; East German storks of the same species migrate southeast through Transylvania, the Balkan Peninsula, and Asia Minor to Africa by way of the Nile Delta. Eggs of East German birds raised in West Germany hatch young that migrate by the route normal to East German birds in an environment where adult birds migrate in the opposite direction—indicating an inherited direction sense (20).

Other Phenomena Supporting the Coriolis Force Theory

Having reviewed the three principal theories of "direction sense," the writer turns to a discussion of phenomena supporting the Coriolis force theory. The phrase "inherited direction sense" from the first sentence of the paragraph is depended on later for transition. This section of the paper deals first with "direction sense" in a number of different animals. The compression of the last sentence is worthy of note since six different references are alluded to.

The larvae of European and American eels (*Anguilla*) afford a striking case of inherited direction sense (21). In the breeding ranges of the two species south of Bermuda, the larvae hatch and are found together but separate as they migrate in opposite directions. Larvae of the American eel swim *west*, metamorphosing into elvers in *one year*, at which time they find themselves off the eastern coast of North America, up whose rivers they swarm to complete their growth. Larvae of the European eel swim *east*, metamorphosing in *three years*, at the end of which time they have reached the coasts of western Europe, in whose streams they complete their development. The well-known ability of the Pacific salmon to return from far out at sea to spawn in the stream in which it was born (22), of the fur seal (*Callorhinus*) to make a long migration on a true course (23), and of the green sea turtle (*Chelonia*) to home indicates that direction sense is most highly evolved in animals living in the fluid media of the earth. It is on these fluid media that Coriolis force acts (trade winds and ocean currents), and it may also affect the fluid in the canals possessed by all these animals in common, even though the fish lack the outer and middle ear. Homing always implies return to a known locale and is known in all vertebrate classes—e.g., in frogs (24), toads (25), box turtles (26), snakes (27), mice (28), and flying squirrels (29).

Direction-finding possibly related to homing and migration is ability to run a maze. Watson (30) found that maze-learning was not impaired in white rats by experimental extirpation of eyes, middle ear, olfactory lobe, or vibrissae, or by anesthesia of feet and nose, or even by elimination of air and temperature currents. But he obtained one result with these animals that he was unable to explain satisfactorily. When the maze was rotated 180° the animals were still able to run it, with some initial hesitation, but when it was rotated 90° none of them could run it. One hardly dares suggest that these animals could run the maze by detecting Coriolis force in the canals and maculae, yet the inner ear alone remained, excepting possible kinesthetic receptors in muscles and joints. In the case of the latter, rotating the maze should have no effect, but if the rats were oriented by Coriolis force, rotation 90° might have the effect noted. It seems possible that, with other senses removed, the inner ear could become supersensitive to Coriolis force.

Other vertebrates learn mazes readily, turtles showing as much aptitude as laboratory rats (31). Birds are slower than rats, but the cowbird (*Molothrus*) and English sparrow (*Passer*) learn faster than pigeons (*Columba*) (32). Birds seem to react to most environmental stimuli with complex but stereotyped instinctive responses, and concentration on learning is difficult (they are "birdbrained," in other words). English sparrows were confused when the maze was reversed, persistently trying to make certain turns as they had been accustomed to do, suggesting a sense of absolute direction.

Bats (*Myotis*) seem to have such a sense. When conditioned to fly to one end of a cage 27 inches long for food, they continued to fly to the same absolute spot in space after the cage had been rotated 180°, even though the white square of cloth on which they had been conditioned was plainly visible at the original end of the cage (33).

Some Peculiarities in the Ears of Birds, Bats, and Aquatic Mammals

Another topic relating to the Coriolis force theory is considered here.

I have found that birds that migrate mainly at night, feeding and resting by day (especially song-birds), have a membranous sac lining the bony wall of the outer ear (18). This sac is composed of cavernous tissue which can be inflated with venous blood by the action of *M. tensor tympani* in damming the auricular vein leading from it. It seems to be a mechanism for covering the drum, which in small birds is ten times the relative size in man. Since the outer ear in such birds is shaped a little like an air scoop, and its opening is thinly veiled by auricular feathers designed to admit air, the head-turning postulated by Ising would, at 40 miles per hour, set up strong plus-minus pressures on the drum. These would make it difficult for the bird to make an estimate of Coriolis force, and it may be under these conditions that the sac is inflated. It is interesting that this tissue is specialized as a cavernosa just in those species making the most phenomenal, chiefly nocturnal, migrations—warblers, buntings, thrushes, golden plover, etc. The diurnal ducks, geese, and swans, generally thought to migrate by visual clues, lack this specialization. In them the sac is composed of relatively undifferentiated connective tissue, but in the ruddy duck (*Erismatura*), which alone migrates habitually at night (34), the sac contains a venous plexus approaching the cavernosa.

Cavernous tissue has also been reported in association with the drum of bats (35), though it may never amount to more than a venous plexus (36). Eschweiler thought the filling of this cavernosa with blood might create tension on the drum in place of the missing *M. tensor tympani* in the pangolin (*Manis*) (37). This tissue has been reported also in the armadillo (*Tolypeutes*) and hedgehog (*Erinaceus*), but in my own dissections of the ear in bats I have not been much impressed with it, nor is the mechanism by which it might be induced to swell evident. However, the cartilage at the base of the pinna seemingly forms a series of valves which may close under the combined

effect of the venous plexus and the extrinsic ear musculature. Griffin and Galambos (38–41) have shown that plugging the ear in bats prevents their hearing their own supersonic cries, but they might momentarily close their ears in homing or migrating, as was suggested for birds. Curiously, neither bats nor birds close the ear in response to foreign objects threatening the drum and thus may only do this in flight when trying to determine direction in the inner ear.

In all these animals having a cavernosa in the ear or an approach to one, a common need to close the external ear exists. The pangolin, armadillo, and hedgehog are burrowing animals, and the need for closing the external ear opening in bats and birds has already been suggested. Aquatic mammals are apparently also able to close the ear (42). And now a curious relationship is seen: vertebrates living in the earth's fluid media—air and water—can either close the outer ear or (like turtles and fishes) have it lacking. It may be coincidence, but these are the animals that exhibit homing and migration most dramatically, and in them the inner ear, suspected of detecting direction stimuli, is peculiarly protected from disturbing effects of the medium in which they live. The olfactory sense may aid salmon in homing to a stream (43) but hardly accounts for its long sea journey—and this sense seems to be totally lacking in birds.

Other Theories of Bird Orientation

In these three paragraphs a number of more or less miscellaneous reports are commented on, rounding out the review.

Rüppell (44) showed that hooded crows (*Corvus*), carried west of their regular migration route in Europe, migrate on a course parallel to it, and Hitchcock found that pigeons trained to fly in only one direction to the loft will, if released off this flight line, continue to fly in this direction (9). Possibly these facts are explained by Matthews' observation that overcast skies have a disorienting effect on homing pigeons (45). At any rate, Kramer has been able to modify the tendency of starlings (*Sturnus*) in an outdoor aviary to migrate in a particular direction by altering the

normal incidence of light with mirrors (46). Conditioned birds were also confused in their selection of feeders, concentrically arranged around a cage, by mirrored light. Although they do not perceive the polarization pattern of the sky, they apparently allow for the daily movement of the sun. Pigeons show the same ability, and Matthews thinks gulls home by sun navigation (47). Unfortunately none of this explains how starlings and the great host of birds migrate at night. Such birds are waifs of the winds and with their poor nocturnal vision could hardly risk alighting at night (48). Once launched on a migratory flight, they must presumably continue until dawn, and a direction sense must be assumed. The moon may be ruled out, for they often migrate on nights when it is not visible. The largest migration waves occur in the spring in the warm sector of a low pressure area, when the sky is overcast and even stars are invisible (49).

It is vital that such waves wait on southerly winds—strong Gulf air masses apt to hold all night. On a west wind, coastal migrants would be carried east while flying north. Dawn would find them over the Atlantic, an error lacking in survival value. So it may be that these waves have evolved in adjustment to the peculiar spring barometric patterns of eastern North America.

Drost (50) believes flying birds respond to radar waves, and Kramer (51), theorizing that they might detect the low-energy, ultra short-wave frequencies emitted by the sun and several stars, tried to obtain evidence. He failed to get reactions of any kind from red-backed shrikes (*Lanius*), flying or perching, to wavelengths of 60 cm, although the field intensities were similar to those used by Drost.

The final paragraph embodies the conclusion of the paper insofar as it is possible to arrive at one on the basis of evidence currently available.

Examples of direction-finding from all vertebrate groups have been assembled here in an effort to discover a common denominator. The maze-learning results may not be examples of the same phenomenon, and for the other examples it is clear that present evidence does not permit generalizing from species to species. The homing ability of gannets does not seem to be of the same

order as that of the Manx shearwater, and the sun-compass supposedly used by starlings in daylight could hardly serve them during their nocturnal migrations. Available evidence suggests that the direction sense is most highly perfected in animals of the fluid media—air and water—animals in which the outer ear is either lacking or may be closed against pressures incidental to movement through the media. A certain amount of circumstantial evidence thus supports the theory that the inner ear may detect Coriolis force and employ it as a compass.

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STUDY SUGGESTIONS

1. Consider the possibilities of the following topics as starting points in defining a problem for a research paper: the principle of ion exchange and the variety of its applications, the importance of Gibbs' "Phase Rule" to engineering, the work of Cuvier, Magendie, and Bernard as

illustrative of the transition from descriptive to experimental methods, the background and significance of the term *Avogadro's number*, evidence offered in support of the "recapitulation theory" in embryology, Whitehead's emphasis on "the organic theory of nature" and on "organism" in contrast to Eddington's emphasis on *analysis*, the background and significance of the term *Occam's razor*. Consult a history of science such as C. Singer's or Sir William Dampier's and list other possible topics for research papers with a historical background.

2. On the basis of what criteria would the example which concludes this chapter be classified as a *review?* What characteristics of the *research paper* does it have? In examining scientific periodicals, how do you distinguish among *reports*, *reviews*, and *research papers?*
3. Select a representative long scientific paper and note the means which the author has used to make the framework of the paper clear to the reader. Do you find that the introductory, transitional, and concluding statements are made directly or indirectly? If this suggestion is followed as a class project, notes may be compared.
4. Can you suggest any research paper problems which might be formulated as a result of considering the area in which the following lines of interest intersect: science and music; aesthetics and automotive design; science and religion; science and poetry; the science of language and chemistry, biology, or medicine; architecture and meteorology; color and the work of Sir Isaac Newton; color and the work of Goethe; color and perception; color and personality; chemical or physical science and the determination of time intervals.
5. Which of the following topics of current interest might suggest problems for a research paper: the sea as a source of food, vaccines for the prevention of poliomyelitis, the sun as a source of power, the transistor, space travel, helicopters, hurricane prediction, changes in life expectancy? Can you supplement these suggestions with others, including topics of particular interest in your locality?

CHAPTER 11 THE REPORT

I. The report as a means of modern communication
   A. Characteristics of the report
   B. How and why reports are initiated
II. Reports according to function
   A. Work reports
      1. Routine or record reports
      2. Periodic reports
   B. Investigative reports
III. Short reports
   A. Outline reports
   B. Memorandum reports
   C. Business-letter reports
   D. Short-form reports

> *Report me and my cause aright.* SHAKESPEARE, Hamlet, V. ii.

I. THE REPORT AS A MEANS OF MODERN COMMUNICATION

Any responsible individual who communicates information based on his activities or investigations to those who want or need it is making a report. Though the written report is an ancient form of communication, its use has been greatly extended in modern times, particularly during the last twenty-five years. The distances across which modern business must be transacted, the gap of specialized knowledge between the executive and the expert, the complex structure of governmental, professional, and business organization, and the growing intricacy of the issues involved have combined to create a situation in which oral reporting is totally inadequate and the written report becomes the conduit through which modern enterprise is channeled.

This pre-eminence of the report has come about inconspicuously. Indicative of the number and variety of reports used in industry is the estimate of a representative firm that approximately sixty regular monthly reports, two daily reports, and fifteen quarterly, semi-annual, and annual reports, as well as numerous single and temporary reports, pass over the desk of the general manager. Likewise, the affairs of the national government go forward by means of reports. As a Naval manual puts it:

> The contact between a coxswain in New Caledonia and CNO in Washington may not be direct or immediately apparent; but it exists. It must, or the Navy will not function. To maintain that contact is the purpose of reports. They are numerous, they often change, they are sometimes bewildering to the inexperienced and they can be infuriating to the veteran. But they are absolutely essential. Everyone recognizes that, from coxswain to admiral. It's a long, wet walk to Washington to make a verbal report.[1]

A. Characteristics of the Report

The word *report,* from the Latin *reportare* (to bring back), sums up the communicative function of the report. Varied in length and subject matter as the many types of written reports are, they all conform to this basic definition. Each is a communication especially designed to convey factual information from a person who has it or who has accumulated it to persons who are entitled to it or who need it, frequently for a practical purpose.

The form of the report varies with the nature of the information to be conveyed, the purpose for which it is wanted, and the person who will receive it. A report is constructed most successfully, according to one authority, when it is "designed to meet certain definite requirements like any structure destined to carry its load." [2] Yet structure alone is not enough. The good report should also be dynamic. Whether long or short, it should move forward with no waste motion from the presentation of its purpose at the beginning to the conclusions or recommendations at the close. Thus, "effective reports

[1] *Yeoman 1 and Chief,* Washington, D. C., United States Government Printing Office, 1950.

[2] J. Raleigh Nelson, *Writing the Technical Report,* New York, McGraw-Hill Book Company, Inc., 1947, p. *vii.*

are at once products of sound craftsmanship and contributions to practical action."[3]

Important decisions may hinge on the information presented in a report or on its recommendations. The location of a new plant, adoption of a new manufacturing process, rejection of a product, changes in personnel policy, allocation of funds—these are some of the decisions that may be arrived at on the basis of reports. Since such policies may involve millions of dollars and may affect the lives of many people for many years, it is essential that the report should be complete and accurate. It may even be required to withstand the test of litigation. The signatures attached to a report, therefore, entail great responsibility.

Since reports serve practical, utilitarian purposes, literary ornament has no place in their composition. The reader is seeking facts, well organized and clearly presented. As one engineer put it dryly: "A report is usually a serious form of writing. The temptation to enliven a report by including an occasional bit of levity should be suppressed; so often those who read reports are devoid of any sense of humor."[4] Those writers who excel in report writing excel in their ability to understand what is wanted, to observe and record data accurately, to analyze it intelligently, and to communicate the results not only through verbal expression but through typographical form, graphs, figures, charts, maps, tables, and equations.

B. How and Why Reports Are Initiated

Because of the complexity of the circumstances which demand reports, no one classification will reveal the full nature of the report. A complete understanding will come only from considering the way in which the report is initiated, its function, and its form.

The person who writes a report is frequently not responsible for initiating its preparation. Consequently the writer must disregard his own interests and wishes in favor of the needs of the person who has requested the report. Reports are often initiated by executive order. Such orders may be either standing or special, or they may stand as

[3] Lisle A. Rose, Burney B. Bennett, and Elmer F. Heater, *Engineering Reports*, New York, Harper & Brothers, 1950, p. *ix*.

[4] By permission from *Technical Report Writing*, by Fred H. Rhodes and Herbert Fisk Johnson, p. 34. Copyright 1941. McGraw-Hill Book Company, Inc.

long as a given piece of work is in progress. Certain reports are required by law, others by the bylaws of an organization. Custom provides the impetus for many reports, including some which are partially self-initiated. A research worker may, for example, decide when to report his results to a technical journal, but the making of such reports is a long-established custom. The report of experimental research is a highly specialized type and has been treated briefly in Chapter 10 in connection with the research paper.

Whether the writer initiates the report or not, he should have a clear understanding of the purpose which the report is to serve. This purpose should be kept in mind throughout the writing process, for it affects everything about the report from the selection of data to the final form of its presentation. If factual data alone are desired, the reporter is responsible for collecting them carefully and for presenting them accurately and clearly. But facts alone may not be enough: " 'The facts speak for themselves' sounds good but is often untrue. In many reports we have to offer estimates, interpretations, hypotheses, theories, predictions, conclusions, recommendations." [5] The writer should understand clearly whether he is expected to confine his reports to facts, to go on to conclusions, or to go still further and draw up recommendations.

Certain types of reports are used in part for promotional purposes. A charity agency, a research foundation, or an industry may invite the support and good will of the public by means of the annual report. A persuasive arrangement of facts then is highly important. Color, layout, and pictorial illustration become dominant features. The appearance may simulate a newspaper, photographs may represent typical cases, or cartoons may dramatize events. If the report is to be worthy of its name, however, the use of these devices must be confined to bringing the facts home to the reader; the report must not distort or misrepresent facts or suggest unworthy motives.

> . . . if a plan is strategic, it must be honest; anything that suggests propaganda, however concealed or camouflaged beneath the massing of facts, any effort of the writer to sell himself or his company to the reader, when he is supposed to be doing something else, will bring his report under suspicion.[6]

[5] Rose, Bennett, and Heater, *op. cit.*, p. 7.

[6] By permission from *Writing the Technical Report*, by J. Raleigh Nelson, p. 18. Copyright 1947. McGraw-Hill Book Company, Inc.

II. REPORTS ACCORDING TO FUNCTION

The report writer should understand the term *function* to mean what the report does: whether it gives an account of work in progress, presents the results of an investigation or survey, or recommends a course of action. Since the functions of reports differ greatly in different fields, terms which classify reports according to function should be understood in relation to their setting. A progress report in industrial research, for example, is quite different from the progress report of a committee.

A broad classification of function—generally applicable—makes a distinction between *work reports* and *investigative reports.* When the writer of an investigative report is expressly charged with making recommendations, the report becomes a *recommendation report.* A *progress report* is an account of the current status of a project or an estimate of achievement in terms of goals.

A work report gives an account of work normally in progress. An investigative report deals with a problem of which a special study is projected. The writer of a work report is already in possession of the facts. The writer of an investigative report must determine the facts before he can undertake the task of reporting them. Between these two types there may be a relationship. In a large industrial plant, for example, the daily reports of tests and analyses are work reports; yet viewed in larger perspective this work is part of a research program involving the investigation of problems.

A. Work Reports

Work reports are of two principal types—*routine* or *record reports,* which are prepared currently as a part of the day's work, and *periodic reports,* which are prepared at intervals to sum up what has been accomplished.

1. Routine or Record Reports

The first type of *work report* which a beginner will probably have to prepare is the *routine* or *record report* of tests, examinations, operations, or performance. (See Section III-A of this chapter.) In some industries projects range from one-person projects to plant projects requiring several technically trained men and in addition three

Do not write in this space

Date Rec ____________

Date Rep ____________

INDIANA STATE BOARD OF HEALTH
BUREAU OF LABORATORIES
1330 West Michigan Street
INDIANAPOLIS 7, INDIANA

Bacteriological Examination of Private Water and Other Waters Not on Schedule

Do not write in this space

Lab. No. H.____________

Ship. No.____________

Code No. H.____________

FILL IN THIS SPACE. USE SOFT PENCIL.
Indiana State Board of Health is to mail report to

(Name) John Doe

(Street) 3250 Guilford

(City or Town) Indianapolis, INDIANA

Do not write in this space

(Name) ____________

(Street) ____________

(City or Town) ____________ INDIANA

All Samples Must Be Received in the Laboratory Not Later Than Friday Noon of Any Week

DESCRIPTION OF SAMPLE

Read Directions on accompanying sheet

Answer all questions—USE SOFT PENCIL

BOTTLE No ____________ COUNTY Marion

1. Source of sample—(Dug, drilled or driven well, spring or cistern) (Underline)
2. Depth 50 ft. Date collected 5-2-52
3. Owner John Doe Collected by John Doe
4. Water used by J. Doe family
5. Location of water supply 3250 Guilford, (Address)
6. Reason for examination new well
7. Age of well 1 week Any recent repairs no
8. Location with respect to privy 50 ft Cesspool 50 ft Septic tank 50 ft Sewers or drains 50 ft ____
9. Top of pump spout—open or closed closed
10. Does pump require priming? no
11. Dug well information Diameter ______ Are walls water-tight to depth of 10 ft or more? ______ Is cover water-tight? ______ Is waste water carried away? ______
12. Driven or drilled well information Diameter 2" Single or double tubular single Depth cased 50 ft. Is there a well pit? no Drained to ______ Has it a water-tight cover? ______ If double tubular, is annular space between the two pipes sealed? ______
13. Spring information Is it walled up and covered? ______ Can spring be flooded by heavy rains? ______
14. Cistern information Material of pipe line to cistern ______
15. Remarks.

S B H 3-4-12 (75M—9-51)

Do not write in this space

LABORATORY EXAMINATION

Portions in Ml	Lactose Broth Positive Tubes 24 Hr	Lactose Broth Positive Tubes 48 Hr.	B G B Positive Tubes On 24 Hr Lactose 24 Hr B G B.	On 24 Hr Lactose 48 Hr B G.B.	On 48 Hr Lactose 24 Hr B G B	On 48 Hr Lactose 48 Hr. B G B	Coliform Confirmed
5-10							
1-1							

REPORT OF SAMPLE

☐ SATISFACTORY At the time of examination this water was bacteriologically safe for drinking and culinary purposes

☐ UNSATISFACTORY. At the time of examination this water was bacteriologically unsafe It should not be used for drinking and culinary purposes unless boiled or treated.

☐ EXAMINATION OF SAMPLE WAS NOT MADE BECAUSE:

☐ The water sample bottle was broken in shipment

☐ There was too long a time between collection of sample and receipt for examination.

☐

☐ WE ADVISE THAT ANOTHER SAMPLE BE SUBMITTED.

Please see recommendations on the accompanying sheet. Numbers ____________

Remarks.

Indiana State Board of Health, Bureau of Laboratories, Indianapolis, Indiana.

Routine or record reports often follow prepared forms. Accuracy is of great importance in their preparation because they are sometimes the basis of higher-level reports.

shifts of operators—records must be kept on this scale twenty-four hours a day.[7] Accuracy is a primary responsibility of the person preparing the record report, for the reliability of all reports at higher levels depends on accuracy at this level.

Like many routine or record reports, the example [8] given on page 255 follows a printed form.

2. Periodic Reports

Whether in business, industry, institutions, or government, staff members in an ascending scale of responsibility receive *periodic reports* from their subordinates or associates. One industrial executive has explained the method used by his department to "follow up" on all regular reports routed to the general manager. (See illustration, p. 257.)

> A wall chart is maintained on which "regular" reports are listed vertically. Horizontally, and in order, appear the days of the month. A green [horizontally striped] square opposite a particular report and directly under a date indicates that the report is "due" on that date. When this due date has been passed during the month and the report has been received "on time," a small yellow [checkered] magnet is placed over the green [horizontally striped] square. If the report has not been received, a red [vertically striped] magnet is placed over the green [horizontally striped] square indicating that the report is late. At the end of each month, a "Report on Reports" is prepared for the Head of the Administration and Planning Department, indicating those reports which were delinquent during the month and the reasons for the delinquency.[9]

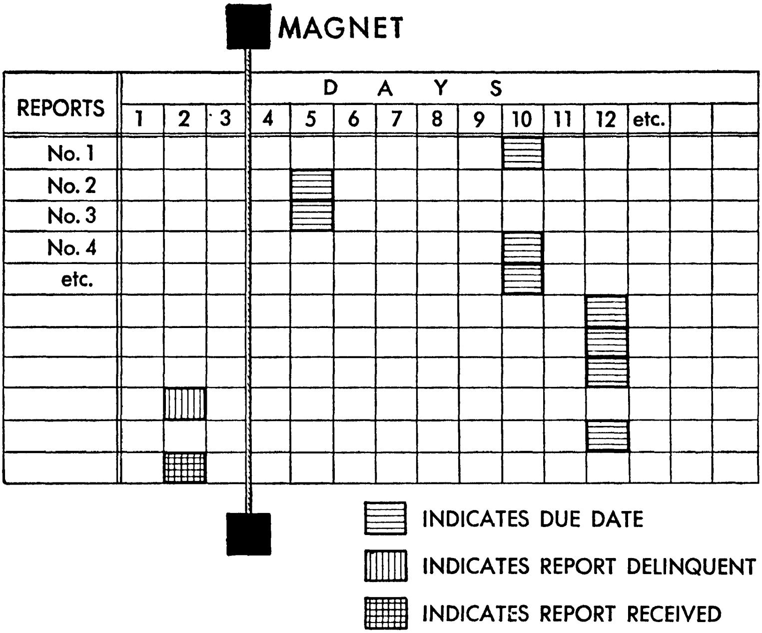
As reports pass through various hands they undergo a sifting process: "So efficient is this routine of condensation by which each individual extracts for his head the essence of the reports submitted to him, that not more than one one-thousandth of the data compiled by the members of a railroad staff appears in the final summary prepared for the stockholders." [10] The year's end has for so long been

[7] E. L. d'Ouville, "Original Records of Experimental Work," *Journal of Chemical Education*, 25:97, February 1948.

[8] This example, classified functionally here, can also be classified according to form as an outline report. (See Section III-A of this chapter.)

[9] Administration and Planning Department, Square "D" Company, Detroit, April 30, 1952.

[10] Ray Palmer Baker and Almonte Charles Howell, *The Preparation of Reports*, rev. ed., p. 97. Copyright 1938, The Ronald Press Company.



Adapted from Administration and Planning Department, Square "D" Company, Detroit, Michigan.

A method of "follow up" for routine reports may be necessary. This wall chart shows at a glance the over-all and individual status of reports for a given month. Colors, instead of patterns, may be used for keying.

regarded as a stopping point for reviewing the year's work that the *annual report* has become a distinct type of periodic report. In certain fields, including public utilities, specific requirements for the annual report have been established by law. Most annual reports include a message from the president, a financial statement, a summary of the year's operations, and a comparative analysis of past achievements and future prospects.

B. Investigative Reports

The variety of problems which may be assigned for investigation and report is almost unlimited. An engineering firm's report may map a route for a highway, a municipal report may present a survey of housing conditions, or an investors' service report may analyze recent trends in the stock market. Obviously, specialized knowledge

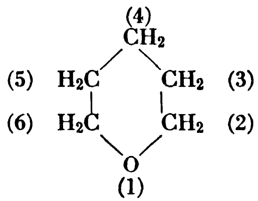
is basic to the successful performance of such functions. Investigative reports depending upon the requirements may be descriptive, analytical, evaluative, statistical, experimental, or historical in approach.

The first investigative report included here follows an outline appropriate to the analysis of chemical products.

NO. 19

DU PONT NEW PRODUCTS BULLETIN

(Electrochemicals Department—Technical Division—
Field Research Section)



TETRAHYDROPYRAN

(SYNONYM: PENTAMETHYLENE OXIDE)

ELCHEM-596

PROPERTIES

Appearance	Colorless, mobile liquid
Odor	Ether-like
Molecular Weight	86.13
Boiling Point	88°C. (190.4°F) at 760 mm.
Specific Gravity, 20/4	0.8814
Refractive Index, N20/D	1.420
Flash Point	-20°C. (-4°F)
Solubility in water at 20°C.. .	9.6 gms./100 gms. water
Solubility of water in tetrahydropyran at 20°C.. . .	2.8 gms./100 gms. tetrahydropyran
Solubility in organic solvents	Miscible with alcohol, ether and most common organic solvents
Boiling Point of Water Azetrope containing 8.5% water by weight	71°C. (159.8°F)

SOLVENT PROPERTIES

Tetrahydropyran is a powerful solvent for many natural and synthetic resins including the following:

Rosin	Manila copal
Ester gum	Shellac
Ethyl cellulose	Chlorinated polyvinyl chloride
Cellulose acetate	Vinylidine chloride copolymers
Polyvinyl chloride	Alcohol-soluble phenolic resins
Vinyl chloride copolymers	Polystyrene
	Chlorinated rubber

Lacquers and plastics can be prepared by dissolving certain organic film-forming substances in tetrahydropyran. The liquids are colorless. Modifiers, dyes, pigments, and plasticizers may be added as desired.

CHEMICAL PROPERTIES

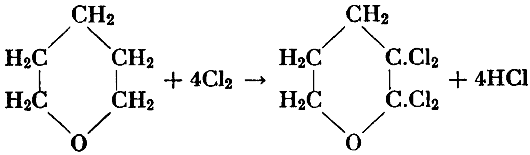
Tetrahydropyran is a cyclic ether, similar to tetrahydrofuran in physical properties and reactions. Chlorination yields mono-, di-, tri-, and tetrachlorotetrahydropyrans. Tetrahydropyran reacts with acid chlorides to form omega-haloamyl esters. Conversion to dihalides such as 1,5-dibromopentane and 1,5-dichloropentane can be effected. Many mono- and di-substituted derivatives of pentane can be obtained from the dihalide. Tetrahydropyran reacts with ammonia and aliphatic and aromatic amines to form piperidine and substituted piperidines.

The following equations illustrate the above reactions of tetrahydropyran:

Chlorination

Tetrahydropyran can be chlorinated at 65°-70°C and then fractionally distilled in vacuo to obtain mainly tri- and tetrachlorotetrahydropyran. Upon distillation at 100°-110°C, 2,3,3-trichlorotetrahydropyran and 2,3,5-trichlorotetrahydropyran can be isolated. The former is stable on distillation at atmospheric temperature, but the latter decomposes to give 3,5-dichlorodihydropyran. On standing, a crystalline deposit of 2,2,3,3-tetrachlorotetrahydropyran comes down which distils at 130°-140°C. Chlorinating tetrahydropyran to 2,3-dichlorotetrahydropyran and then distilling at ordinary pressure, with evolution of hydrogen chloride, yields 5-chlorodihydropyran, which

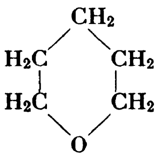
can be chlorinated further to the 2,3,3-trichloro derivative. Also, 2,3-dichlorotetrahydropyran can be hydrolyzed with water in the presence of calcium carbonate to 2-hydroxy-3-chlorotetrahydropyran, which reacts with 5-chlorodihydropyran to form bis-(3 chloro-2-tetrahydropyryl) ether.



2,2,3,3-Tetra-chlorotetra-hydropyran

Lit. Ref. Brit. Pat. 571,265 and 571,266—Soc. Dyers and Colourists 62, 55, Feb. 1946.

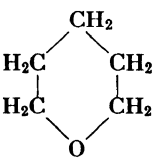
Reaction with Acid Chlorides



$+ CH_3COCl \rightarrow Cl.CH_2.CH_2.CH_2.CH_2.CH_2.O.\overset{O}{\overset{\|}{C}}.CH_3$

Acetyl chloride — Omega-chloroamyl acetate

Conversion to Dihalides



$+ 2NaBr + H_2SO_4 \rightarrow$

$Br.CH_2.CH_2.CH_2.CH_2.CH_2.Br + Na_2SO_4 + H_2O$

1,5-Dibromopentane

Lit. Ref. J. Chem. Soc. 1945, 48-51. C.A. 39, 2748-9.

The halogen atoms on the above compounds are highly reactive. For example, they can be replaced by cyanogen (CN) radicals which, in turn, can be reduced to primary amine groups or hydrolyzed to carboxyl groups.

$Br.CH_2.CH_2.CH_2.CH_2.CH_2.Br + 2NaCN \rightarrow$

$NC.CH_2.CH_2.CH_2.CH_2.CH_2.CN + 2NaBr$

Pimelonitrile

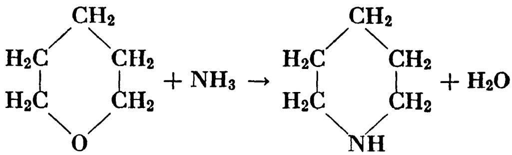
$$NC.CH_2.CH_2.CH_2.CH_2.CH_2.CN + 4H_2 \rightarrow H_2N.CH_2.CH_2.CH_2.CH_2.CH_2.CH_2.CH_2.NH_2$$

Heptamethylene diamine

$$NC.CH_2.CH_2.CH_2.CH_2.CH_2.CN + 4H_2O + 2HCl \rightarrow HOOC.CH_2.CH_2.CH_2.CH_2.CH_2.COOH + 2NH_4Cl$$

Pimelic acid

Reaction with Ammonia



Piperidine

Lit. Ref. J. Am. Chem. Soc. 66, 1710—4(1944).
C.A. 38, 6178.

HANDLING

We recommend the following precautions:

Keep tetrahydropyran away from heat and open flame.
Use with adequate ventilation.
Avoid prolonged or repeated breathing of vapor.
Avoid prolonged or repeated contact with skin.

Although tetrahydropyran is fairly stable to peroxide formation, there is a possibility of explosion hazards. To avoid these, tetrahydropyran should never be distilled or evaporated without first testing it for peroxide and removing the latter if found to be present. Tetrahydropyran as provided by the Electrochemicals Department contains a stabilizer to inhibit peroxide formation. As a routine precautionary measure, however, even the stabilized material should be tested for peroxide before it is subjected to distillation or evaporation. (On distillation, most of the stabilizer remains in the residue and the distillate is therefore unprotected.) The following method is suggested for testing for and removing peroxide:

SUGGESTED METHOD OF TESTING FOR AND REMOVAL OF PEROXIDE

The method consists of the use of a mixture of ferrous sulfate heptahydrate, $FeSO_4 \cdot 7H_2O$, and sodium bisul-

fate, $NaHSO_4$. The ferrous sulfate destroys the peroxide while the sodium bisulfate provides an acid condition which favors the peroxide destruction.

To use this method, the per cent of tetrahydropyran peroxide present should be determined by the usual titration. (This consists of agitating a sample with acidified potassium iodide solution and titrating the liberated iodine with standard sodium thiosulfate solution.) Then there is added to the tetrahydropyran at ordinary temperatures somewhat more than the theoretical quantity of an equimolecular mixture of the ferrous sulfate heptahydrate and sodium bisulfate. The mixture is shaken or stirred vigorously for a short time. A sample is then titrated and if peroxide is still present, the agitation is continued until no test for peroxide is obtained. Usually a period of a few minutes suffices. Since the reaction results in the liberation of a small amount of water from the $FeSO_4.7H_2O$, the product may be dried if desired by stirring with or allowing the liquid to stand for a time in the presence of solid caustic soda.

AVAILABILITY

Tetrahydropyran is available at present in limited quantities for research and development purposes.

July 11, 1946

This second example illustrates the importance of making a clear distinction between recommendations and other features of the report. The first paragraph concludes the discussion, Section IV presents specific recommendations, and Section V, the final section, offers general conclusions.

Why Is Modern Architecture Modern? [11]

What is most striking about the number of instances of Modern architecture already on college campuses is the enormous variety represented in design types. Of course, this merely reiterates the fact that the "Modern style" in architecture is above all a changing, testing evolution which has never become sufficiently static to justify the cog-

[11] "Report of the Committee for the Revision of the Larson Plan," prepared under the direction of Dr. Walter L. Creese, University of Louisville, June 1949.

nomen "style." Nor can such a result be adjudged completely desirable. For three reasons this is perhaps what makes it most vital and alive: 1. Its flexibility of design allows for the adoption of any technological or engineering improvement and a corresponding aesthetic response in the appearance of the building, not true in Georgian or Gothic. 2. Although new crimes are constantly committed in the name of its latitude of choice, when a person of true originality arrives, his genius has a chance to fulfill itself completely. Unrestrained by long-standing or deep-seated traditions, adventurous American builders have long shown a proclivity for veering off toward experimental individualism. Sometimes its results have been comic, sometimes tragic, but the integrity of the architecture of Thomas Jefferson, H. H. Richardson, Louis Sullivan and Frank Lloyd Wright and many other architects at work today would seem to indicate that when it finally makes a return, it does so superbly. 3. Modern architecture helps to keep our buildings in tempo with current political, social and economic changes. The retreat into a few stylistic categories which characterized the late nineteenth and early twentieth centuries was in part, at least, due to the underlying hope that America was over its erratic adolescent growth and was ready to settle down. We know now that this was thankfully not true, either for the whole country or more particularly for the American university.

IV. A PERMANENT COMMITTEE

For the purpose of bringing the campus development into a better system of coordination, the Committee for the Revision of the Larson Plan recommends that after its dissolution a second, permanent committee be organized consisting of members of the administration, representatives of the faculty, elected by the Senate, a member from buildings and grounds and possibly one from the athletic department. All elements should have sufficient representation, but the group should not be so large as to hinder effective action. Its duties should be light, but it should consider itself as responsible for the maintenance of consistent aims of which the whole university community might be aware. If either or both a landscape and a campus plan architect is appointed, we believe that this group should serve as a liaison body between them and the school. If not, then the committee should be given some authority to generally oversee the disposition of buildings, walks, parking spaces, planting and other objects.

V. CONCLUSION

The character and appearance of the physical plant deserves permanent consideration if for no other reason than its importance as a symbol. While it may be argued that it is impossible to tell a university

by its campus any more than a book by its cover, and that the real worth of a school lies in its library, the minds of its scholars and students, and in the competence of its administration, this argument is only pertinent within certain limits. If any twentieth century individual discounts the value of socio-physical symbols, so indispensable to primitive man, let him try to visualize New York without thinking of skyscrapers, Washington without the Capitol and White House, or his own alma mater without its campus. For the alumnus, the potential freshman and the general public, as well as present students and faculty, the buildings of the college must constitute the essential physical fact around which other, more nebulous impressions are gathered. Great architecture has only resulted when people have had the hardihood and persistence to try to incorporate their most abstract conceptions in wood or stone, steel or concrete. If we neglect the outward appearance of our campuses, do we not also deny our inner image of a university of its rightful power to inspire external beauty above and beyond the casual thoughts of a sadly makeshift world?

III. SHORT REPORTS

For convenience, reports are often classified according to length, as well as function (see pages 254-64). *Short* reports are ten pages or less; *long* reports may run to many volumes. There are four basic types of short reports: the outline report, the memorandum report, the business-letter report, and the short-form report.

A. Outline Reports

The *outline report* is a mimeographed, multilithed, or printed form used principally for routine and periodic reports. If the writer must make a routine report for which no specified form has been provided, he may devise his own form, remembering to use the same topic headings in the same order for all comparable reports in a series. The outline report often has a heading giving the subject, the date, and the name and position of the person making the report.

The following examples are representative of forms used in industry for making outline reports.[12]

[12] The example on p. 255, classified functionally as a work report, is classified according to form as an outline report.

Form No. 9-40—3000-2-46-St.

PAINT COMPLAINT FORM

(EXTERIOR WORK)

Inspected By__________ Date__________

Dealer's Name__________ Dealer's Address__________

Owner's Name__________ Owner's Address__________

Painter's Name__________ Painter's Address__________

Type of building Frame ☐. Brick ☐. Stone ☐. Stucco ☐.

Type of roof: Tile ☐. Tin ☐. Composition ☐. Shingle ☐ Insulation__________ Name Brand

Date of painting__________ Date when defect was first noticed__________

Nature of complaint__________

TYPE OF FAILURE

	Yes	No		Yes	No
General tint failure	☐	☐	Mildewing	☐	☐
Fading in spots	☐	☐	Metal staining	☐	☐
Dirt collection	☐	☐	Gas discoloration	☐	☐

Structural defects found where water could enter.

	Yes	No		Yes	No
Window frames	☐	☐	Wet basement	☐	☐
Louvres	☐	☐	Lumber siding near ground	☐	☐
Headers	☐	☐	Lack of ventilation in side walls	☐	☐
Roof	☐	☐			
Insulation	☐	☐	Were siding butts leaded?	☐	☐
Warped siding or trim boards	☐	☐	Were valley gutters leaded?	☐	☐
Absence of flashings or defective flashings	☐	☐	Were hanging gutters leaded.	☐	☐
Poor drainage of surface water	☐	☐	Were nails driven in and puttied?	☐	☐

Have similar failures occurred on previous paintings on this job? Yes ☐. No ☐.

What was done to overcome these previous defects?__________

Have failures occurred on the garage or other outbuildings in the same manner and was the same kind of lumber and paint used? __________

Indicate side of house upon which defect has occurred and the degree of failure in such terms as slight, medium or bad.

N W E S

	Slight	Medium	Bad		Slight	Medium	Bad
☐ Cracking	☐	☐	☐	☐ Peeling to bare wood	☐	☐	☐
☐ Flaking	☐	☐	☐	☐ Checking	☐	☐	☐
☐ Blistering	☐	☐	☐	☐ Washing or chalking off	☐	☐	☐
☐ Peeling of previous paint	☐	☐	☐				

Applied on new or previously painted surface: New ☐ Old ☐.

Condition of old paint at time of repainting

Chalking	☐	Cracking	☐
Checking	☐	Flaking	☐
Peeling	☐	Blistering	☐

Number of old coats in film__________ Adherence of old coats to underlying surface__________

Brand of paint previously used__________

(Continued over)

LABORATORY—Return To Office For Filing

Kurfees Paint Company, Louisville, Kentucky.

An outline report, often a long prepared form, provides a checklist for the procedure of investigation.

KURFEES PAINT COMPANY

Employee Rating Sheet

Name of Employee__________ Dept.__________ Title__________

Present Rate__________ Date of Last Increase__________

Time on Present__________ Lost Time__________ Times Tardy__________

	10 9 8	7 6 5	4 3 2	1 0 00
Job Performance	Does more than is expected	All that is expected	Barely makes his standard	Does not make his standard
Job Quality	Superior	Good	Average	Unsatisfactory
Job Knowledge	Thorough	Good	Fair	Insufficient
Attitude	Enthusiastic	Interested	Indifferent	Lacks interest
Initiative	Exceptionally resourceful	Very resourceful	Occasional effort	Very little
Dependability	Excellent	Good	Fair	Poor
Neatness	Excellent	Average	Fair	Sloppy
Leadership (Personality)	Inspires confidence	Self-assured	Not too confident	Lacks assurance
Leadership (Supervisory)	Excellent direction	Good direction	Fair direction	Poor
Conduct	Above criticism	Seldom subject to criticism	Subject to frequent criticism	Subject to constant criticism
	10 9 8	7 6 5	4 3 2	1 0 00

Is worker satisfied with what he is doing?________ If not, Why?________

Does worker wish to transfer?________ If so, to which other Department?

____

Is he qualified to accept a better position?________ Where?________

Do you recommend a transfer?________ Or Discharged?________

Do you recommend an increase?________________

Remarks: ____________________

____

____

Date__________ Supervisor__________

B. Memorandum Reports

Memorandum reports are used chiefly for communication between administrative levels and between different departments within an organization or industry. Such a report may consist of a single sentence, or it may run to several pages. Many firms have their own printed memorandum forms. When no form is supplied this arrangement may be followed:

```
                                   June 5, 1952

From:    J. R. Andrews, Vice-president

To:      A. B. Taylor, General Manager

Subject:  Run No. 476
```

The short memorandum has no complimentary close, and initials may replace the signature. With a longer and more formal memorandum a complimentary close such as "Respectfully submitted" and a signature may be used. The body of the long memorandum follows the usual pattern of a business communication. The opening paragraph states the essential business. This paragraph or the paragraphs immediately following may present the conclusions reached or the recommendations to be made, depending on whether the writer feels they will be more favorably received here or at the end of the communication. The middle paragraphs add whatever facts or explanations are needed. A final paragraph may present conclusions or recommendations if these points have not been adequately covered in the opening paragraphs. Tabular, mathematical, or graphic data may be included if their use does not unduly extend the length of the report.

The choice between the memorandum report and the more elaborately organized formal report should not be made on the basis of length alone. The memorandum is suited to the reporting of an event or activity of limited scope, while the formal report is appropriate for the coverage of a considerable period of time and a variety of activities.

The following memorandum makes a final report on work done in examination of certain materials. In this example the directive and the report made in response appear on the same memorandum form.

Cross Index: 436, 51, 1655

cc J. E. Masters
G. W. Neumann
L. K. Scott
J. S. Long

DEVOE & RAYNOLDS CO., INC.

Research Department

FINAL REPORT SCS-25 DATE May 9, 1952

INVESTIGATOR S. C. Spalding, Jr. COMPLETED August 13, 1952

SUBJECT

EXAMINATION OF ALKYDOL PRODUCTS EMULSION RESINS

You have received samples of emulsions from Alkydol Products Company. Such samples included polystyrene resin dispersion, alkyd resin dispersion, copolymer of styrene butadiene and alkyd resin dispersion. Please use this work order to report the work you have done in examination of these materials.

J. E. Masters

JEM: jc

P. S.

Attached hereto is the Technical Service Bulletin on these products. Please attach this bulletin to the file copy of the work order when the final report is written.

J. E. M.

* *

Report:

Alkydol Labs products Alkyd-O-Mer, 8106, 8200, 7004 (respectively an alkyd emulsion, an alkyd-emulsion GRS type latex blend, a GR type latex) were received and rated as films against a Syntex 40 Hi Sol. emulsion made using Emulsifier #107 at 2% of F.F.S. and ca 60% N.V.M. and .04%Co 0.5 Pb as driers. Alkyd-O-Mer 8106 is not as good in drying speed and does not dry to a clear film as the Syntex 40 emulsion. Alkyd-O-Mer

8200 is matched by a blend of Syntex 40 emulsion with Dow's 762K butadienestyrene emulsion to give 43 1/2% of 762K solids in the dried film.

S C. Spalding, Jr.

SCS:jc

C. Business-letter Reports

The *business-letter* form is used for a report when it is desirable to emphasize a person-to-person relationship. It is favored also for reports offering professional advice or opinion. The business letter (see Appendix B, p. 441) is not usually employed for reports of more than a few pages since it is difficult to maintain a personal tone throughout a lengthy document.

The effective use of the business-letter form in reporting to a group is illustrated by the letter, reprinted here, from the president of the Santa Fe Railway to the stockholders following the severe floods in the summer of 1951. The presentation of the material in this report is carefully adapted to the persons addressed. While a casual reader might easily consider the report unnecessarily painstaking and detailed, the stockholders—many of them small-town investors—had a more than casual interest in damage to the Santa Fe system. An informal, person-to-person tone helps to convey the desired note of reassurance.

THE ATCHISON, TOPEKA AND SANTA FE RAILWAY SYSTEM
80 East Jackson Boulevard, Chicago 4, Illinois

F. G. GURLEY
President

Chicago, Illinois, July 23, 1951

TO THE STOCKHOLDERS:

I returned to the office this morning from an inspection trip of our lines in Kansas and Missouri and write to tell you of high water and flood damage in those states - especially in Kansas.

There were severe rains during June. We had high water difficulties and traffic interruptions in the drainage of the Kaw and along Walnut Creek, a tributary of the Arkansas River. In Missouri we had some

troubles at crossings of streams which flow into the Missouri. We had reinstated normal train service almost everywhere by July 9.

During the evening and night of July 10 there were terrific rains in Kansas - for instance, six to seven inches in the vicinity of Emporia. These rains affected the territory drained by the Kaw, the Osage, and various branches of the Neosho. All of our lines lying to the east of a line drawn through Newton - Wichita, Kansas, were damaged sufficiently to prevent train operation. The Kaw assumed destructive flood proportions, exceeding the height of the disastrous flood of 1903 by five or six feet at Kansas City, Kansas.

Following the disastrous flood of 1903 the Kaw Valley Drainage District was created - its principal purpose being to protect land and property in the Kansas City, Kansas, area. Santa Fe lands and property were a substantial part of the lands and property protected by dikes built by the Kaw Valley Drainage District. The design and height of the dikes were based upon protection against flood waters of the proportions of 1903.

Early in the morning of July 13 the Kaw in the vicinity of Kansas City, Kansas, was substantially higher than the dikes, and large areas were inundated, including our valuable terminal known as Argentine. In some locations there was as much as twenty-two feet of water over our track. Fifty-one Diesel locomotive units were under water, as were some steam engines and some 4,000 freight cars. There was about two and one-half feet of water in our shops at Topeka and much of the line from Topeka to Kansas City, which is in the Kaw Valley, was under water. Service on our transcontinental line was suspended between July 10 and July 20.

The combination of (a) revenue losses, and (b) increased expenses produced by these flood waters will amount to some millions of dollars. It has been impossible in the time that has elapsed since the beginning of the trouble to form anything like an accurate estimate. The damage was that incident to the cutting action of water and the damage that is implicit in equipment and property being under water. The fifty-one Diesel engines, for example, were not damaged as damage is inflicted by the force of impact incident to a serious derailment, but batteries were

severely damaged or ruined - battery damage will probably be about $4,000 per engine. Other than that, the principal "repairs" to the Diesels will be drying of motors and the removal of mud and slime, especially from moving parts. The principal damage to freight cars was that incident to water, mud and slime in journal boxes, in brake cylinders, and in air brake valves.

The money loss, of course, is serious, yet I feel warranted in assuring you that in the light of the volume of our traffic in 1951, it will not be "too serious" - I appreciate that it is difficult to make an accurate distinction between "serious loss" and "not too serious loss."

Our organization, following the sudden and terrific rains on July 10 so controlled all train movements that there were no derailments. While several passenger trains, carrying hundreds of passengers, were held at outlying stations for as long as two days, the passengers were well cared for - they appreciated the circumstances, and there have been no serious complaints.

One cannot forecast now the amount of damage to inundated shipments in freight cars, nor can we say now what our liability may prove to be under applicable liability laws.

Now as to the future - what to do in the light of these high waters and this destructive flood.

In the places which may be described as those "out in the country" we should make such improvements as increasing bridge openings, and in low places raising the track to higher elevations. These are the procedures which we have followed historically when experience has demonstrated that the changes were necessary. In other areas, notably in the valley of the Kaw, our future course will be decided upon following conferences in which the Army Engineers and interested Communities will participate. Since the days when the Kaw Valley Drainage District was formed, the Congress, through passage of various flood control acts, has charged the Army Engineers with certain obligations for plans and has made certain appropriations for the control of flood waters. The President of the United States and various other Federal Officers have made inspection of these areas since July 13 and there is a meeting scheduled at Kansas

City, July 25, to consider what should be done. This meeting will be attended by representatives of the Federal Government, the States, the Communities, and individual companies. My purpose is to attend this meeting. I am quite confident that measures will be taken which will protect us against a repetition of the 1951 flood waters.

Sincerely,

(signed) F. G. Gurley

An analysis of the Santa Fe report shows that the plan and paragraphing are well adapted to its purpose. It opens with a simple statement of subject and closes with a declaration of intended action. Of the nine intervening paragraphs, two recount the history of the flood, and a third describes previous efforts at flood protection. The following five deal with damage: (1) with the extent of the inundation, (2) with the losses, particularly to equipment, (3) with the money loss, (4) with inconvenience to passengers, (5) with damage to freight shipments. Then comes a short transitional paragraph introducing the concluding statement of future plans.

The tone of care and confidence maintained throughout this letter is strengthened by such concrete references as those to Diesel engines and other equipment and by the use of railroad terms. The unobtrusive use of "I," particularly in such passages as "I returned to the office this morning," "I feel warranted," "I appreciate," and "I am quite confident," gives the reader a feeling of being in close contact with the situation and with those responsible for its control.

D. Short-form Reports

Like the memorandum, the *short-form report* is used largely for communication within the company or industry, and the needs of the individual laboratory or division determine the format used. This type of report is impersonal and objective in style. Centered or marginal headings indicate the subdivisions. General information—the subject of the report, date, responsible agency, number, and such other data as are desired—is given on the title page or on the upper half of the first page. Thus the short-form report is a somewhat streamlined version of the long-form report. (See Chapter 12.) Reports of this type are easily handled and quickly read, and the limita-

tion as to length encourages a concise style and compact arrangement.

In the following example the title page has several headings which serve various company record needs. The division of the report into sections headed Purpose, Procedure, Comments, and Conclusions facilitates rapid examination. The specific nature of the conclusions should be noted.

WESTINGHOUSE
ELECTRIC & MANUFACTURING COMPANY
SHARON, PA.

Date March 12-1948

SHARON WORKS LABORATORY

Report No. 70

Memo No.

Subject: Adhesives for Laminated Pressboard

Copies to: Mr. J. G. Ford, Manager, Manufacturing Engineering--for file
Mr. W. G. James, Division Engineer, Power
Mr. R. L. Brown, Section Engineer

Budget or Order No. 6-SH-700373

☐ Confidential

Figuring Book No. ____ Page ____

☒ General Company Distribution

Test Record Book No. 726 Page 68

File No. MP-500.1

APPROVALS—

J. G. Ford ~~Works~~ Manager, Mfg. Engrg. — G.W. Minor Engineer

PE-306

Westinghouse Electric & Manufacturing Company, Sharon, Pennsylvania.

This is the title page for the short-form report following. The format is governed by such individual company needs as distribution and cataloguing.

PURPOSE

To determine if an adhesive other than treated paper M794-1 can be used for laminating pressboard used in oil-filled transformers.

PROCEDURE

Standard pressboard PDS 5181-1 was built up to a thickness of two inches according to P.S. SH-115348 by using the following materials: (1) treated paper M794-1; (2) Lepage's Dextrin glue #201, M7667-3; and (3) hide glue M6249. Pressboard beams 2" x 12" were then cut from each of the experimental plates of laminated material. This was to simulate the use of laminated pressboard as lead supports in power transformers.

The beams were then supported at each end (on a 12" span) and placed in the Tinius Olsen machine, where a measured load could be applied to the center of the beam. The load was increased until failure of the beam occurred.

Small pieces of the laminated material (approximately 110 grams) were placed in 400 cc. of Wemco "C" oil at 90°C for one week. At the end of this time, the acidity of the oil was measured and compared with the acidity of a blank sample of oil under the same conditions.

The 60-cycle one-minute hold creep strength of the laminates was measured along the glue lines at distances of one and two inches. These tests were made in air on untreated samples and in oil after exposure to oil at 90°C for one week.

I Breaking Load of Beams (in pounds)—12" Span

	Type of Adhesive		
Test No.	794 Paper	201 Glue (M7667-3)	Hide Glue (M6249)
1	2340	1765	1040
2	2240	1955	950
3	2020	1895	1020
4	2500	1850	1030
Ave.	2275	1866	1010

II Oil Acidity after One Week at 90°C—MgNaOH/gr.oil

Blank	Pressboard Bonded with: 794 Paper	201 Glue	Hide Glue
0.022	0.023	0.023	0.046

III Creepage Strength along Glue Lines—60-Cycle one-Minute Hold

Sample	Air 1"	Air 2"	Oil 1"	Oil 2"
Pressboard bonded with:				
794 Paper	16 KV	27 KV	16 KV	27 KV
201 Glue	16 KV	27 KV	16 KV	27 KV
Hide Glue	16 KV	27 KV	16 KV	27 KV

Remarks: Flash-over at electrodes before failure by creep.

COMMENTS

All of the pressboard beams failed parallel to the laminations at the values given above. Treated paper M794-1, which we are now using, gives a laminate which has a breaking load approximately 25 per cent greater than a laminate made with #201 glue (M7667-3). Hide glue gives the poorest bond of all the samples tested, since beams made with this adhesive fail at less than 50 per cent of the value of laminates made with treated paper.

There was no appreciable change in oil acidity as a result of exposure to pressboard bonded with treated paper or dextrin glue. However, an appreciable increase in acidity was evident after exposure to pressboard bonded with Hide glue. The quantities of laminated pressboard which are used in our transformers are so small in comparison with the quantity of oil that this increase in acidity probably will not have any noticeable effect on the oil.

The actual creepage strength along the glue lines could not be measured because flash-over at the electrodes occurred before failure by creepage. An attempt was made to measure the creepage strength at a distance of six inches, but this value was not within the limits of the laboratory test outfit.

Treated paper M794-1 costs 25 cents per pound as compared with a cost of 5 cents per pound for dextrin glue M7667-3. This difference in cost will not be affected by the extra labor involved in coating the pressboard with this glue. It is estimated that a saving of approximately $1,600 per year can be realized by using this dextrin glue if only labor and material costs are considered.

In addition, we have found that pressboard laminated with dextrin glue does not require as long a cooling cycle after pressing as does pressboard laminated with treated paper. This factor in itself eliminates the need for large quantities of cooling water and, as well, reduces delays in production which occur when laminated pressboard is made.

The shop also believes that pressboard laminated with dextrin glue will be easier to cut and will reduce the cost of maintenance for saws. This latter item is now considerable and can be attributed partly to the difficulty of cutting pressboard laminated with treated paper.

The pressboard which we now get from our suppliers in thicknesses greater than 1/4 inch is laminated by gluing the required number of plies to the desired thickness with dextrin glues. It has been our experience that pressboard such as this is satisfactory in every way and has shown no tendency to delaminate.

In view of these facts, it is recommended that dextrin glue be used instead of treated paper for laminating pressboard. Although no specific tests were made in this investigation to determine the resistance of dextrin glue to Inerteen, we know from past experience that water-soluble dextrins such as the #201 covered herein are resistant to Inerteen. Process Specification SH-115348 will be revised in the near future to specify the use of this glue for laminated pressboard used in oil- and Inerteen-filled transformers.

CONCLUSIONS

(1) Pressboard beams laminated with treated paper M794-1 have a breaking strength approximately 25 per cent greater than the strength of beams laminated with dextrin glue.

(2) Pressboard beams laminated with dextrin glue M7667-3 have a breaking strength approximately 80 per cent greater than beams made with hide glue M6249.

(3) The acidity of oil is not appreciably affected by the various adhesives covered in this report.

(4) The creepage strength of the pressboard laminates is not affected by the various adhesives.

(5) Based on material costs, approximately $1,600 per year can be saved by using dextrin glue for laminating pressboard. Additional savings can be realized in the time and amount of water needed for cooling and in maintenance of saws.

(6) It is recommended that dextrin glue #201 (our M7667-3) be used in place of treated paper M794-1 for laminating pressboard for oil-filled transformers.

CHAPTER 12 | THE REPORT, CONTINUED

IV. The long-form report
- A. Arrangement
  1. Cover and title pages
  2. Letter of transmittal and foreword
  3. Table of contents
  4. Summary or abstract
  5. Body of the report
  6. Bibliography and appendix
- B. Preparation
  1. Collecting, selecting, and arranging material
  2. Writing and revising the report

V. Major considerations in report writing
- A. Reaching the reader
- B. Applying the principles of composition

IV. THE LONG-FORM REPORT

A project or investigation of consequence to which considerable time has been devoted demands a *long-form report.* (For an example of a long-form report, see Appendix A, p. 422.) In making long reports it becomes increasingly important to employ an arrangement which will enable the busy person to grasp the content and essential significance of the report quickly.

A. Arrangement

In a full-scale formal report the following arrangement of parts is widely accepted:

Cover page
Title page
Letter of transmittal
Table of contents
Summary or Abstract
Body

Bibliography
Appendix

Certain circumstances may demand the inclusion of such additional elements as letter of authorization, foreword, list of tables, list of illustrations, distribution lists, signatures, and index.

1. Cover and Title Pages

The title of a report should be specifically descriptive and should include key words by which the report may be indexed. The *title page* gives, in addition to the title, the name of the person or agency preparing the report, the place of issuance, and the date. It may also include such items as the name of the person authorizing the report, the serial number, and the abstract. If the report is bound, it may have a heavier *cover page* which includes all or part of the information given on the title page. Examples of a cover page and of a title page are shown on pages 280 and 281.

2. Letter of Transmittal and Foreword

The *letter of transmittal*, which usually precedes the table of contents, is the personal message which accompanies the report from the author to the recipient, usually the person who authorized it. From one point of view this letter is like the covering letter sent with any enclosure; from another it is the writer's opportunity to make any necessary comments on his report and to stress his chief findings. Certain points are customarily included: (1) a reference to the letter of authorization, indicating the date, (2) a statement of submittal or transmittal, (3) an indication of the purpose and scope of the report, (4) an acknowledgment of any assistance received. Sometimes the letter of authorization, as well as the letter of transmittal, is bound with the report.

The writer may use the letter of transmittal to stress any feature of the report which he thinks particularly significant. Nevertheless, this letter, like any other business letter, should be governed by the "you attitude," and the needs and interests of the reader should take precedence over those of the writer. Apologies and other forms of negative suggestion should be avoided.

INDUSTRIAL
ENGINEERING
DIVISION

DU PONT

ED-1948
AUGUST, 1948

INSTRUCTIONS FOR THE

PREPARATION OF

ENGINEERING DEPARTMENT REPORTS

E. I. du Pont de Nemours & Company
Incorporated

ENGINEERING DEPARTMENT

WILMINGTON, DELAWARE

E. I. du Pont de Nemours & Company, Wilmington, Delaware.

A cover page for the long-form report presents the pertinent data in a form such as shown here. It is used in addition to the title page, not in place of it.

Serial No. ED-1948

E. I. du Pont de Nemours & Company

ENGINEERING DEPARTMENT

Wilmington, Delaware

August, 1948

INSTRUCTIONS FOR THE PREPARATION OF ENGINEERING DEPARTMENT REPORTS

Prepared by

F. F. MIDDLESWART

ABSTRACT

This report is the guide to be used by Engineering Department personnel when preparing reports. It supersedes Engineering Department Report, Serial Number ED-1447, "Instructions for Preparing Formal Reports on Investigations and Experimental Work," and is expanded to include instructions for the preparation of informal and memorandum reports. Flexibility of arrangement and variety of expression are stressed to permit adapting a report to fit the type and importance of the subject matter presented.

The following letter of transmittal with its accompanying letter of authorization was issued with a printed report of sixty-three pages.

LETTER OF TRANSMITTAL [1]

THE PRESIDENT'S COMMISSION ON HIGHER EDUCATION

WASHINGTON, D. C., *December 11, 1947.*

DEAR MR. PRESIDENT:

On July 13, 1946, you established the President's Commission on Higher Education and charged its members with the task of examining the functions of higher education in our democracy and the means by which they can best be performed.

The Commission has completed its task and submits herewith a comprehensive report "Higher Education for American Democracy." The magnitude of the issues involved prompted the Commission to incorporate its findings and recommendations in a series of six volumes of which this is the first.

The Commission members and the staff are grateful for the opportunity which you have given us to explore so fully the future role of higher education which is so closely identified with the welfare of our country and of the world.

Respectfully yours,

GEORGE F. ZOOK,
Chairman.

The Honorable
The PRESIDENT OF THE UNITED STATES.

LETTER OF APPOINTMENT OF COMMISSION MEMBERS [2]

THE WHITE HOUSE

WASHINGTON, D. C., *July 13, 1946.*

DEAR —— ——:

As veterans return to college by the hundreds of thousands, the institutions of higher education face a period of trial which is taxing their resources and their resourcefulness to the utmost. The Federal Government is taking all practicable steps to assist the institutions to meet this challenge and to assure that all qualified veterans desirous of continuing their education have the opportunity to do so. I am confident that the combined efforts of the educational institutions, the States,

[1] "Higher Education for American Democracy," Vol. I, "Establishing the Goals," a Report of the President's Commission on Higher Education, Washington, D. C., December 1947.

[2] *Ibid.*

and the Federal Government will succeed in solving these immediate problems.

It seems particularly important, therefore, that we should now re-examine our system of higher education in terms of its objectives, methods, and facilities; and in the light of the social role it has to play.

These matters are of such far-reaching national importance that I have decided to appoint a Presidential Commission on Higher Education. This Commission will be composed of outstanding civic and educational leaders and will be charged with an examination of the functions of higher education in our democracy and of the means by which they can best be performed. I should like you to serve on this body. Among the more specific questions with which I hope the Commission will concern itself are: ways and means of expanding educational opportunities for all able young people; the adequacy of curricula, particularly in the fields of international affairs and social understanding; the desirability of establishing a series of intermediate technical institutes; the financial structure of higher education with particular reference to the requirements for the rapid expansion of physical facilities. These topics of inquiry are merely suggestive and not intended to limit in any way the scope of the Commission's work.

I hope that you will find it possible to serve on this Commission.

Very sincerely yours,
(*signed*) *Harry Truman*

Unlike the foregoing letters, which are official government letters, the next example of a letter of transmittal follows the usual business form.

TENNESSEE VALLEY AUTHORITY [3]
Knoxville, Tenn., August 4, 1950

Mr. George F. Gant, General Manager,
Tennessee Valley Authority, Knoxville, Tenn.

Dear Mr. Gant:

Technical Report No. 23, Surveying, Mapping and Related Engineering, is the third of a series of special reports being prepared to cover certain phases of engineering and construction work common to all projects designed and constructed by TVA in the unified development of the water resources of the Tennessee River system.

[3] "Surveying, Mapping and Related Engineering," Tennessee Valley Authority, Technical Report No. 23, Washington, D. C., United States Government Printing Office, 1951, p. *iii*.

These special technical reports have been planned as a companion series to technical reports on the individual projects and record the results of experience gained on TVA projects in specialized fields over a period of years. It is recommended that Technical Report No. 23 be printed as a public document.

Yours very truly,

C. E. BLEE, Chief Engineer

In reports addressed to a special group or to the general public, a *foreword* often replaces the letter of transmittal. The foreword is signed by the author or by the executive who is responsible for the report. The substance of the foreword quoted here parallels that of a letter of transmittal but is addressed to all readers, not to an individual.

FOREWORD[4]

This preliminary factual report on the survey of university patent policies which the National Research Council has been conducting is released for the information and guidance of research scientists, university administrators, patent attorneys, industrialists, and others concerned with the conduct, administration, and support of scientific research and the handling of patentable discoveries and inventions growing out of research on the university campus.

For more than thirty years the National Research Council has been interested in the patent problem. In 1917 the United States Commissioner of Patents, with the approval of the Secretary of the Interior, requested the National Research Council to appoint a committee to investigate the Patent Office and the patent system, with a view to increasing their effectiveness, and to consider what might be done to make the Patent Office more of a national institution and more vitally useful to the industrial life of the country. The report of the Patent Committee, appointed by the Council in compliance with that request, was issued in 1919 as the first publication in the Council's Reprint and Circular Series.

The Council's present Committee on Patent Policy, under whose sponsorship this survey of university patent

[4] Archie M. Palmer, "Survey of University Patent Policies," Preliminary Report, Washington, D. C., National Research Council, 1948, p. *i.*

policies has been conducted, was created in 1933. Through the years this committee has given continuing consideration to the various aspects of the patent problem and has held several conferences on the general subject and on specific patent questions.

The present survey has been conducted under the direction of Dr. Archie M. Palmer, who has been a member of the Council's Committee on Patent Policy since its inception in 1933. With thoroughness and acuity, resulting from deep personal interest and extended experience with the problem as university administrator and research worker, he has analysed the prevailing practices of the universities and has prepared this preliminary report on his findings.

Through its Committee on Patent Policy and the director of the survey, the National Research Council gratefully acknowledges its indebtedness to the college and university officials, scientists, and others who liberally contributed information and data concerning existing policies and practices; to Research Corporation which made the survey possible through a generous grant to the National Research Council without placing any restrictions on the conduct of the survey or assuming any responsibility for the findings; to the various professional journals which have published preliminary material on the survey; and to Hugh Samson and Paul F. Johnson who assisted the director of the survey in the collection and analysis of the basic material used in the preparation of this report.

GEORGE B. PEGRAM

(Chairman, Committee on Patent Policy, National Research Council)

3. *Table of Contents*

The table of contents, usually headed simply Contents, directs the reader to the page numbers of different sections of a long report. It is prepared after the report is complete by revising the outline from which the report was written and adding the necessary page numbers. The headings and page references should correspond exactly, even to articles, prepositions, and punctuation, to the headings of divisions and subdivisions in the text of the report. The table of contents offered here shows a typical arrangement.

CONTENTS[5]

4. Summary or Abstract

For the convenience of readers a *summary* or *abstract* of the entire report is often included between the table of contents and the body of the report, or between the title page and the report. This summary or abstract presents briefly—frequently in a single paragraph—the essence of the report: its purpose, its chief findings, and its conclusions or recommendations. Thus readers who may not wish to read the entire document are informed of its essential contents. In some reports, especially in industry, this abstract appears on a separate sheet so that it can be detached and circulated independently. The

[5] "75 Years of Service to the Nation," Bell Telephone System, 1951.

reports of some agencies close with a verbatim repetition of the opening summary. Little distinction is made in general between the terms *summary* and *abstract* as applied to this part of the report. Some writers prefer to reserve the term *abstract* for the type published by abstracting journals, which summarizes the contents more thoroughly with less emphasis on purpose and conclusion. (See Chapter 13.)

The following abstracts introduced reports of from ten to eighteen pages; the introductory summaries or abstracts of extremely long reports may be more extended. The first example is entirely descriptive; the second goes on to give results and conclusions. The third abstract devotes a paragraph each to achievement, method, procedure, and conclusion.

ABSTRACT

This paper describes the effect of exposure for 10,000 hours (about 14 months) at 900, 1050 or 1200°F on microstructure, hardness at room temperature, and notch-impact strength at different temperatures of 18 ferritic and austenitic steels applied in service at elevated temperature.[6]

ABSTRACT

This paper describes the important factors that must be considered in a study of engine power loss due to combustion chamber deposits. Data are presented to show the effects of fuel composition, sulfur and lead concentration, and lubricant composition, engine design, and operating conditions on deposit-power loss. The influence of engine operating conditions existent during the accumulation of deposits, and the importance of the engine conditions selected to evaluate the magnitude of the deposit-power loss are illustrated. It is indicated that deposits cause power loss by thermal and physical restriction of the intake charges, and by reduction of thermal efficiency. It is concluded that differences in effect among the majority of commercial fuels and lubricants are probably small although relatively large differences may exist in certain critical engine applications. The engine operating conditions under which the deposits are accumulated are a major factor in deposit-power loss. Constant-speed, constant-load operation represents the most adverse condition. Engine design is

[6] G. V. Smith, W. B. Seens, H. B. Link, and P. R. Malenock, "Microstructural Instability of Steels for Elevated Temperature Service," American Society for Testing Materials, Philadelphia.

indicated as the principal means of alleviating the problem where it does exist, and several design features which will minimize deposit-power loss are discussed.[7]

ABSTRACT

A rolling method for the fabrication of longitudinally tapered sheet of aluminum alloys has been designed and proved on a pilot scale. The developed method utilized the principle of synchronization of screwdown speed with roll rotation velocity to accomplish the desired purpose. This synchronization was achieved by means of an auxiliary electrical control system used in conjunction with a conventional rolling mill.

Methods were developed for producing both linear (one taper per unit) and multiple (two tapers per unit) tapers. In addition, a cyclical, repetitive mode of operation was developed by means of which tapered sheet can be produced by a continuous rolling (high speed production) method simulating conventional strip rolling methods.

The range of flatness attainable for tapered sheet was determined on a pilot scale utilizing flattening facilities which were locally available.

The investigation indicated that the developed rolling method is applicable to the commercial production of tapered sheet, and that the necessary rolling and flattening equipment are within practical design limits.[8]

5. Body of the Report

The substance of the report comprises the *body*, which customarily includes an introduction, conclusion, and such intervening subdivisions as the subject matter of the report requires. All other parts of the report are secondary to the body and are provided to increase its availability and usefulness.

6. Bibliography and Appendix

Many reports end with the concluding section of the body, but numerous others add a *bibliography* or an *appendix* or both. The bibliography—often called References or Literature Cited—is a list

[7] H. J. Gibson, C. A. Hall, and A. E. Huffman, "Combustion Chamber Deposition and Power Loss," Ethyl Corporation Research and Engineering Department, Detroit.

[8] J. B. English and R. E. Jordan, "The Development of Rolled Tapered Sheet of Aluminum Alloys," sponsored by the United States Air Force Materiel Command, Reynolds Metals Company, October 1951.

of sources used in compiling the report. It is used, especially in published scientific, scholarly, or technical reports, to acknowledge sources, to direct the reader to additional information, and to comply with copyright laws. Various forms of documentation, including different combinations of bibliography and footnotes in the text, are used by different groups and journals. (See Chapter 14.)

The appendix is a supplementary section designed for pertinent material which the writer wishes to include but cannot present at length in the text without impeding the reader or throwing the report out of balance. Through the use of the appendix the writer may offer additional evidence for his conclusions. This material may include copies of documents, statistics, data sheets, mathematical computations, instructions and procedures, personnel lists, and illustrations.

B. Preparation

The preparation of a long report is a complex process. The writer's work will involve initial preparation, assembling, studying, and selecting material, planning the report and making an outline, writing the report, revising the report, and putting the report into final form.

This outline from the Office of Naval Research divides the process into four major steps with a detailed analysis of each one.

SCIENTIFIC REPORT WRITING[9]

Step I—Study

1. Collect material
2. Check details
3. Consider purpose of report
   - Who will read it?
   - Why does he want it?
   - What does he require?
   - How will he use it?
4. Draft a thesis sentence

Step II—Plan

1. List topics to be covered
2. Decide on topics for
   - Introduction
   - Body of report
   - Terminal section

[9] Scientific Personnel Division, Office of Naval Research, Washington, D. C.

3. Make an outline
4. Sketch headings and sub-headings

Step III—Write

1. Introduction: state subject, purpose, plans; summarize results, conclusions
2. Body: tell equipment used, action taken, facts found; analyze results
3. Terminal Section: summarize; draw conclusions; make recommendations; give final emphasis
4. Abstract: condense report to paragraph or two
5. Prepare Table of Contents
6. Arrange Appendix, Bibliography

Step IV—Criticize

1. Examine as a whole; check balance of parts, soundness of pattern; eliminate confusion
2. Check agreement of title, table of contents, introduction, and abstract; check clarity of subject, purpose, plan
3. Check terminal section for agreement with introduction, for proper emphasis
4. Check headings for agreement with table of contents, for proportion of parts
5. Examine text; check topic transitions, coherence and length of paragraphs, sentence structure, and word usage

1. Collecting, Selecting, and Arranging Material

If the writer is solely responsible for the report, he should not slight the initial period of preparation. It involves studying the purpose of the report and the wishes of the person or persons who authorized it. The directive or letter of authorization should be carefully examined. Before going further, the writer should be sure that he knows what is wanted and how far his responsibility extends. A review of plant or institutional practice and of reports of similar character will be helpful. These considerations will be influential in determining the general make-up of the report.

Source materials for reports include data obtained from experiments, from laboratory tests, and from field observations; letters and other documents in company files; minutes of meetings and hearings; records of interviews; questionnaires; and published materials of all kinds. (See Chapter 4.) Much raw data in industrial plants is recorded in notebooks. The notebook system is given pref-

erence because a numbered, dated, and bound book with numbered pages offers proof of priority in work involving patents.[10] This legal protection offsets the advantages of the card and loose-leaf filing systems popular in library research and in many laboratories where patents are not involved. Whatever the sources of the material, selection according to the purpose of the report will be necessary before the writer can plan the body of the report.

The writer may have to draw up an original outline, or he may have at hand a conventional pattern into which he can fit details. In either case the writer should think through his material thoroughly before undertaking the outline of a report. Many beginners attempt to prepare an outline before studying their material thoroughly. Such a procedure is comparable to attempting to set up categories for itemizing the merchandise in a warehouse before finding out what the warehouse contains. (For further discussion of the outline, see Chapters 5 and 10.)

2. *Writing and Revising the Report*

Once a tentative outline is set up, the writer is ready to compose the body of the report. Here, as in the research paper, the introduction and conclusion demand separate consideration. (See Chapter 10, Section II-B.)

The first section of the body of the report, whether formally labeled Introduction or not, serves to orient the reader to the purpose and subject matter of the report. In this section the writer states the purpose, defines the scope, and explains the plan of the report. Sometimes, particularly in a report of a purely factual investigation, an anticipatory summary of the conclusions is included in the introduction. However, in delicate or controversial questions of policy, it is frequently wise to lead the reader through the logical considerations that resulted in a particular conclusion before presenting him with that conclusion. The complexity of the matters covered in the introduction will determine its length.

The following introduction from a report of the Testing Division of the Douglas Aircraft Company serves to explain to the reader the occasion and purpose of the report.

[10] Marlin T. Leffler, "Abbott Laboratories Notebooks," *Journal of Chemical Education,* 25:99-100, February 1948.

Introduction:

Failures of brake pressure accumulator bolts (part No. 1243720) during and after assembly by the manufacturer have been reported. The details and assemblies are manufactured for . . . by the . . . , and are used on the . . . , . . . , and some . . . models.

The assembly consists of two hemispherical, flanged aluminum alloy forgings bolted together at the flanges by steel bolts. Installation is normally made by tightening each bolt until it elongates .005–.006 as measured by a micrometer. The assembly is proof tested at a hydraulic pressure of 6,000 psi. The engineering drawing for the bolt requires the use of 4130 steel (An-QQ-S-684) heat treated to a tensile strength of 150–180,000 psi.

This investigation was conducted to determine the cause for breakage, and provide data to be used in determining the disposition of parts from the same batch as the installation failures.

The arrangement of the material between the introduction and the conclusion varies with the subject matter of the report. Investigative reports usually cover the methods or procedure followed, the findings, the results derived from an analysis of the findings, and a discussion of the results. The inexperienced writer often does not perceive the importance of this part of the report because he tends to proceed too quickly to conclusions. The evidence must be adequately presented before conclusions can be drawn. In fact, authorities have attributed greater value to the data included in a report than to the comments on those data. This distinction between fact and judgment is also helpful to the student who has difficulty in developing his paper to the required length.

A judgment ("He is a fine boy," "It was a beautiful service," "Baseball is a healthful sport," "She is an awful bore") is a *conclusion,* summing up a large number of previously observed facts. The reader is probably familiar with the fact that students, when called upon to write "themes," almost always have difficulty in writing papers of the required length, because their ideas give out after a paragraph or two. The reason for this is that those early paragraphs contain so many such judgments that there is little left to be said. When the conclusions are carefully excluded, however, and observed facts are given instead, there is never any trouble about the length of papers; in fact, they tend to become too long, since inexperienced writers, when told to give

facts, often give far more than are necessary, because they lack discrimination between the important and the trivial.[11]

The concluding section of the body of the report may be called the summary, conclusion, or recommendations. In strict usage the term *summary* denotes a synopsis while *conclusion* denotes the propositions arrived at as a result of the study. The term *recommendations* is used when the purpose of the report is to recommend a course of action. The individual items in this section are often numbered as an aid to clarity and precision. Many reports include a terminal summary as well as a summary or abstract preceding or following the table of contents. (See Section IV-A-4.) Even though these two summaries may contain some of the same materials, they serve different purposes for the reader.

Of the two examples of conclusions given here, the first represents a numerical summary, the second offers conclusions of a more general nature.

CONCLUSION

The following has been done in this paper: (1) The mathematical nonlinearized equations (neglecting viscosity and heat conduction) have been obtained in conical form; (2) an invariance relation for these nonlinear equations has been proved; (3) it was shown that an attached shock, two-shock pattern is not possible for air; (4) the possibility of the existence of reciprocal flows has been discussed; (5) the patching curve relations were obtained, and with the aid of these, (6) the existence of a form of transonic singularity in the straight attached wedge shock was obtained; (7) it was shown that a certain type of attached shock flow cannot exist.[12]

CONCLUSIONS

Smoke, cinder, and fly-ash emission can be reduced to conform with air pollution ordinances. It is largely a problem of educating the small plant owner and operator in the benefits and necessity of cleaning up their stacks.

Many small plants are already conforming to air pollution ordinances; others must improve conditions. Some of the latter plants, however, can be made non-violators without the addition of dust traps or collectors. It can be and has been accomplished through careful,

[11] S. I. Hayakawa, *Language in Action*, New York, Harcourt, Brace and Company, 1941, p. 50.

[12] S. F. Borg, "On Unsteady Nonlinearized Conical Flow," *Journal of the Aeronautical Sciences*, 19:85-92, February 1952.

intelligent firing practices and elimination of dust accumulations in the hoppers, breeching, and stack bases. For certain plants a change of fuel size has satisfactorily reduced stack dust. To aid in smoke abatement, modern overfire jets are being increasingly used to accompany proper firing practices.

When there is a need for dust traps or collectors, most problems can be solved with inexpensive low-draft-loss equipment.[13]

The accessory parts of the report (see Section IV-A) are prepared after the first draft of the body of the report has been written. Then the entire report is revised and polished and the copy checked for completeness, clearness, coherence, and correctness, as well as for tone, smoothness of phrasing, and probable effect on the reader. (See Chapter 7.) After the writer has made the necessary changes in the manuscript, he is ready to prepare the report for typing, hectographing, mimeographing, multilithing, photographic processing, or printing.[14] The entire process of preparing a report is a long one, but, as has been pointed out, "to prepare an outline, a preliminary draft, and a final report may appear to involve the expenditure of an excessive amount of work, but experience shows that usually less effort is required than is needed to write a good report directly from the data." [15]

V. MAJOR CONSIDERATIONS IN REPORT WRITING

The fundamental principles of report writing are the same as those of other forms of written composition. Some of these principles, however, apply with particular force to the report because of its special purposes.

A. Reaching the Reader

Since the report is often an assignment and is always designed to meet the needs of a particular reader or group of readers, the writer has a direct obligation to make his report serviceable to the reader.

[13] William S. Major, "Small Industrial Plants Can Abate Smoke and Dust," Bituminous Coal Research, Inc., Reprinted from *The Plant,* June 1950.

[14] B. H. Weil and John C. Lane, "Reproduction Techniques for Reports and Information Service," *Journal of Chemical Education,* 25:134-41, March 1948. B. H. Weil, ed., *The Technical Report: Its Preparation, Processing, and Use in Industry and Government,* New York, Reinhold Publishing Corporation, 1954.

[15] By permission from *Technical Report Writing* by Fred H. Rhodes and Herbert Fisk Johnson, p. 7. Copyright 1941. McGraw-Hill Book Company, Inc.

The individual who will receive the report and be responsible for action on it is often, especially in industry, personally known to the writer. If not, at least his requirements are known. As one authority has explained, "My most important function was not inserting commas or revamping awkward sentences but helping the weary investigator plan the presentation of his results to meet the requirements of the man paying the bill." [16] The reader's individual interests will influence the writer's choice of analogies and illustrations. The knowledge with which the reader approaches the paper will affect the number of definitions and explanations which must be provided. In fulfilling the purpose of the report the writer must often subordinate his own desires and interests. There is an ever-present temptation to display his knowledge, describe his difficulties, or air his views, but this temptation must be overcome.

The skilled report writer keeps in mind diverse means of reaching the reader. Maps, tables, charts, graphs, and pictures are among the many forms of communication other than verbal expression which are appropriate in reports. (See Chapter 15.) In scientific and engineering reports, tables, technical graphs, equations, flow sheets, maps, and diagrams will appear. The business report will mainly employ statistical tables, as well as linear, bar, pie, and picture graphs. The promotional report will include, in addition to relatively simple graphic illustrations, abundant pictorial material and also pictorial analogies.

The external design of the report is a valuable means of facilitating the reader's study of the report. Lines, spacing, variations of type, and centered or marginal headings may call attention to the divisions and subdivisions. Emphasis may be given to important points by spacing, capitalization, underlining, color, and even arrows or "boxes." Meaningless ornament, such as fancy arrangements of asterisks, is undesirable. Printed reports, especially in business and industry, often appear as attractive booklets or brochures.

B. Applying the Principles of Composition

The report writer, however skilled in planning and designing his report to meet the needs of the reader, is expected in composing it

[16] J. Raleigh Nelson, *Writing the Technical Report*, New York, McGraw-Hill Book Company, Inc., 1947, p. *x*.

to show above all else competence in verbal expression. It is assumed that anyone who has advanced to the writing of long reports understands the principles of composition. (See Chapter 9.)

In applying these principles the report writer may find that while coherence and emphasis may be achieved by the same means used in other types of papers, unity becomes a special problem in report writing because of the multiplicity of detail and variety of subject matter to be covered. A careful subordination of minor to major points is the best means of coping with excessive detail. The use of an appendix and of explanatory footnotes will sometimes help. The problem of varied subject matter is especially likely to be troublesome in the annual report which must handle numerous unrelated matters. One means of handling this difficulty is to select a "theme" or focal point of interest for each yearly report, as is often done in planning meetings and conventions.

Unity of tone is as important as unity of subject matter. The more vivid clichés, such as "scraping the bottom of the barrel" or "a rubberstamp," may at times be effective in informal reports to put over an idea, but a serious, formal report should not descend to colloquial or slangy language. The tone of a report may, as the occasion demands, be highly scientific, scholarly, or technical, soberly factual, breezy, cordial and friendly, or matter of fact. But whatever the tone, it should be maintained consistently throughout the paper.

The style of a report should be simple, direct, and concise. (See Chapter 8.) Except in reports in memorandum or business-letter form, the style is usually impersonal. This impersonality may demand considerable use of the passive voice, though the active voice is generally considered more forceful. Passive constructions with impersonal or expletive openings are unfortunate, such as "It was observed in the course of the demonstration" for "The demonstration showed" or "There was evidence to be observed in the data" for "The data pointed to." "Deadwood" should be painstakingly pruned from the report. The inexperienced report writer is often charged with substituting paragraphs for sentences and pages for paragraphs.

Logic of both substance and expression affects the degree of respect which a report commands. (See Chapter 6.) Probably the commonest flaw in logic is extending the conclusions beyond the scope of the data. Not only should facts be kept distinct from conclusions, but

any limiting factors in the data should be clearly repeated in the conclusions.

The making of reports forms a large part of man's whole scheme of communication. In keeping with this emphasis, new employees entering business and industry have been well advised to cultivate skill in expression through such "basic tools" as the report.

> As an employee you work with and through other people. This means that your success as an employee—and I am talking of much more here than getting promoted—will depend on your ability to communicate with people and to present your own thoughts and ideas to them so they will both understand what you are driving at and be persuaded. The letter, the report or memorandum, the ten-minute spoken "presentation" to a committee are basic tools of the employee.
>
> If you work as a soda jerker you will, of course, not need much skill in expressing yourself to be effective. If you work on a machine your ability to express yourself will be of little importance. But as soon as you move one step up from the bottom, your effectiveness depends on your ability to reach others through the spoken or the written word. And the further away your job is from manual work, the larger the organization of which you are an employee, the more important it will be that you know how to convey your thoughts in writing or speaking. In the very large business organization, whether it is the government, the large corporation, or the Army, this ability to express oneself is perhaps the most important of all the skills a man can possess.
>
> Of course, skill in expression is not enough by itself. You must have something to say in the first place. The popular picture of the engineer, for instance, is that of a man who works with a slide rule, T square, and compass. And engineering students reflect this picture in their attitude toward the written word as something quite irrelevant to their jobs. But the effectiveness of the engineer—and with it his usefulness—depends as much on his ability to make other people understand his work as it does on the quality of the work itself.[17]

This chapter has described the great variety of current practices in report writing. An understanding of these practices will help the writer on a job to learn rapidly from experience, provided he does not let rigid conventions prevent a new approach to changing needs and problems. Anyone who has seen the changes in business and industry during the past twenty-five years will realize that many changes will take place during the working years of those who are

[17] Peter F. Drucker, "How to Be an Employee," reprinted by special permission from *Fortune*, 45(5):126-27, May 1952. Copyright 1952 Time Inc.

now getting their training. No wonder the counsel of the experienced is that the analyst "must never quit his education because once he does his value is gone." [18] Inevitably, the report writer will be called on in the future to learn and develop new techniques to meet new demands placed on the report.

STUDY SUGGESTIONS

1. Obtain several annual reports and analyze them, covering the points referred to in the foregoing chapter. What resemblances and differences do you note among the reports of municipalities, industrial organizations, charitable organizations, insurance companies, etc.? How do you account for these differences?
2. Collect as many examples of reports as possible and classify them as to form. Among the reports of different companies do you find greater similarity in the format of outline, memorandum, short-form, or long-form reports? Why?
3. Make a thorough analysis of the Stone and Webster report given in Appendix A, considering the purpose, format, parts included, arrangement, organization, style, and use of illustrations.
4. Prepare in outline-report form a check list covering the various styles, types of punctuation, salutations and complimentary closes used in business letters. Examine a group of letters from representative firms and fill out an outline report for each letter.
5. Analyze the reports prepared for Exercise 4, and in a memorandum report to your instructor, summarize fully the results of your analysis.
6. List as many reports as possible which have to your knowledge been circulated on your campus or within your organization. In each instance, how was the report initiated, who prepared it, what was its purpose, what was its form, and to whom and by what means was it distributed?
7. Plan and carry out a survey of student opinion concerning some problem on your campus, such as poor attendance at convocations, parking, student housing, or campus publications. Analyze and interpret your findings, make any recommendations you think are justified, and present the results as a short-form report.
8. Examine your experience for opportunities for observation which might provide subject matter for a report. The following list may offer suggestions: industrial practices observed in part-time or temporary jobs you have held, provisions for serving food on your campus, styles of architecture represented on your campus, campus

[18] D. B. Keyes, "Training Men to Appraise and Develop Markets for Chemicals," *Chemical and Engineering News*, 27:488, February 21, 1949.

services such as the bookstore, post office, commissary. Write a letter report, presenting the information you have obtained to a person whom you may assume to have requested it.

9. Many students have sources of information which can be drawn on for long-form reports. Analyze your experience for opportunities to make: (a) a case study—a specific study of some practice or process in an institution or industry with which you are acquainted; (b) a comparison—a comparative study of two related practices or situations; (c) a recommendation report—an analysis of a local situation with recommendations for its improvement; (d) a survey—an inquiry into practices or situations in a number of different plants or institutions.
10. Many reports require extensive library research, the motivation for which must come from the needs or interests of the individuals initiating the report. Consider the following as possible topics for such reports: advertising practices in a selected group of periodicals, the circulation and reception of American movies abroad, design and performance in automobiles of European manufacture, opportunities for engineering or technically trained graduates, work of the recently established educational foundations, scholarship programs, new developments in the different phases of communication, the distribution of the modern newspaper, the relative place of soaps and detergents, the present industrial status of pure silk, new ideas in merchandising, accounting practices in relation to tax requirements, adjusting the gas supply to seasonal requirements, prefabricated houses, planning and zoning regulations, traffic signals, reforestation projects, new developments in lighting (either street or residential), electronic beams, difficulties in developing and maintaining city water supplies, automatic classifying and index cards, microfilm, microcards, suburban shopping centers, educational opportunities in rural areas.

CHAPTER 13 SPECIAL TYPES OF PAPERS

> *. . . all advances in science consist either in enlarging the range of experience or in expressing the regularities found or to be found in it.* HERBERT DINGLE, Presidential Address, Royal Astronomical Society, London, 1953.

The types of papers with which this chapter is concerned have been evolved over a period of many years to meet specialized needs of science or have been adapted by scientific writers to their needs. Of these types of papers the most sharply defined is the abstract. The case history is almost as widely used as the abstract, but its form is less standardized. The description of device or instrument and the exposition of process are sometimes separate papers, sometimes a part of longer papers. The book review, though not of scientific origin, has an established place in scientific periodicals.

I. THE ABSTRACT

A number of scientific periodicals, known as abstracting journals, are devoted wholly to the publication of abstracts. In general, an *abstract* is a summary of an article which has appeared previously elsewhere and includes a bibliographical reference to the original article. Authors frequently have occasion to prepare abstracts of their own papers: some scientific journals require that each paper submitted for publication be accompanied by an author abstract, scientific societies in advance of their meetings issue programs in which appear abstracts of the papers to be presented, and an author abstract often appears at the beginning of a long report. While abstracting journals sometimes make use of author abstracts, it is usually considered that better perspective and greater objectivity are achieved if the abstract is prepared by another writer thoroughly familiar with the author's field.

The most generally useful type of abstract is the *informative abstract* which presents in condensed form the content of the original. Since the abstract is a summary and not a criticism or evaluation, the writer of the abstract should preserve an attitude of the utmost objectivity, regarding himself only as a medium for conveying to the reader the most accurate idea possible of the content of the original article. The abstracter should follow the article's order and sequence and should keep as nearly as possible the same proportion and emphasis; no major division or essential material should be overlooked or omitted. The abstract should not include anything which was not a part of the original article, and its author should not express his own opinion of either the subject or its presentation.

A second type of abstract, called the *descriptive abstract,* defines the coverage of the original article and indicates the contribution it has made but does not summarize it. The description of the original article as offered by this type of abstract must be expressed in objective terms, since evaluation of the original is not a part of the abstracter's task. While the descriptive abstract is more serviceable than a mere reference, its usefulness is necessarily limited.

A. Writing of Abstracts

For certain purposes the abstract may be limited by editorial policy to a maximum length of 225 or 300 words. Since an abstract may thus be only a fraction of the length of the article, its writing demands rigorous exclusion of all illustrative detail and involved discussion. Though it is not necessary to enclose in quotation marks short phrases taken verbatim from the original, the condensed style of the abstract will seldom permit extended use of the original wording. The skilled abstracter will cultivate verbal economy. A group of cases, for example, may be reduced to an adverbial clause, a statement of purpose to an infinitive, a list of conclusions to a series of parallel phrases.

An abstract is frequently a single paragraph. Sometimes a short paragraph is devoted to the introduction or statement of purpose, a paragraph to the results, and a paragraph to the conclusions. It is seldom possible to allow a paragraph to each division of the paper, and no attempt should be made to include topical headings or formal outlines.

B. Examples of Abstracts

The first two examples of informative abstracts show how a considerable amount of technical information can be presented in the condensed style of the abstract. It will be noted that the example from *Chemical Abstracts* employs certain acceptable abbreviations which are characteristic of technical writing in the chemical field.

Time and stress effects in the behavior of rubber at low temperature. J. R. Beatty and J. M. Davies. J. Applied Phys. 20, 533-9 (1949).—The stiffening of rubber-like materials at low temp. involves several different phenomena, sometimes with their effects superimposed. One of these is crystn. This is a rate process which is generally very fast at high stresses and very slow at zero stress. In these expts. at temps. near $-25°$ and under a shear stress of about 148 lb. per sq. in. the dynamic modulus of the rubber increased at a rate convenient to study. Correlation with x-ray data showed that crystn. was likely responsible for the increase in stiffness. The rate of change of stiffness increased rapidly with increase in applied stress, and there was no optimum rate at $-25°$ as has been found for unstressed rubber. The degree of vulcanization influenced the rate of change, tighter cures giving smaller changes. Neoprene-FR, GR-S, and polybutadiene, which ordinarily show little evidence of crystn., showed very definite but small

increases in stiffness. Mixing GR-S with natural rubber seems to limit the crystn. of the natural rubber rather effectively, but apparently Neoprene-FR does not mix intimately enough with natural rubber to affect the crystn. of the latter appreciably.—H.P.K.[1]

The example from *Biological Abstracts* is somewhat longer than the average abstract, but is an effective and adept condensation of a complex subject.

Splithoff, C. A., Origin and development of the erect posture. Surg., Gynecol. and Obstet. 84(5):943-949. 5 fig. 1947.—Human posture is shown to have evolved through a series of progressive changes, beginning with the prehistoric Devonian fish, 350 million years ago. Amphibians evolved land adaptation some 50 million years later. Because of poor adjustment to terrestrial locomotion, their abilities were probably limited simply to obtaining food with little attempt made to move for any distance. Walking continued to be cumbersome in the ancient reptiles, whose limbs were widely separated. From *Cynognathus*, a creature between reptile and mammal which existed 175 million years ago, and could run on land, has evolved the more highly developed *Notharctus*, an arboreal lemur-like primate. Other lemurs, monkeys, and apes retained the ability to climb trees. The only ape able to walk upright on the ground is the gibbon. The skeleton of this ape begins to appear almost human in type. The gibbon has the ability to walk by up-ending one tower of the suspension bridge to which the shoulder and pelvic girdle, together with the spine, may be compared, and balance it on its rear tower, represented by the pelvic girdle. The ability to walk upright evolved from the habit of sitting upright and from the habit of brachiating or swinging from limb to limb. The ability to walk has been perfected in the human through modification of the entire skeleton, but principally the pelvis and lumbosacral spine. It is true that certain apes can walk upright, but the pelvis is not mechanically suited for such progression. The muscle pattern of ape and man is similar, yet there is a difference in function and in comparative size; and a difference in the focal point of action of the gluteal muscles which is the secret of human ability to walk. In the ape the external iliac surface points backward at right angles to the acetabulum, rather than externally or outward as in the human. Thus human posture evolved by progression from water onto land, then into the trees and to the ground again.—K. W. Buchwald.[2]

The third informative abstract appeared in the section "Industrial and Other Applications" of *Psychological Abstracts*. Though brief,

[1] *Chemical Abstracts*, 43:6853 e, September 10, 1949.
[2] *Biological Abstracts*, 22(1):No. 73, pp. 7-8, 1948.

it is in proportion to the length of the original article, which is included with it here.

Chandler, William R. (Harvard U., Cambridge, Mass.), *The relationship of distance to the occurrence of pedestrian accidents.* Sociometry, 1948, *11*, 108-110.—From information taken from the files of the Brookline Police Department on 264 pedestrian-vehicle accidents, the distance between place of residence and point of accident was measured. The data indicate that there is an inverse proportionality between the distance from residence and the frequency of accidents.—H. H. Nowlis.[3]

THE RELATIONSHIP OF DISTANCE TO THE OCCURRENCE OF PEDESTRIAN ACCIDENTS [4]

This study investigates the relationship between pedestrian accidents on the one hand and the pedestrians' distances from their homes at the time of the accident on the other.[1]

The data were taken from the traffic files of the Police Department [2] of Brookline, Massachusetts, and include all cases of pedestrian-vehicle (i.e. auto, bus, and trolley) accidents in the files for the years 1946 and 1947. There were in all 284 accidents of this type recorded of which 20 cases had to be excluded because of inadequate information. The 264 remaining cases which were used constitute the entire sample to which the present article refers. The distance between the place of residence and point of accidents was measured [3] in each case to the nearest quarter of a mile over the shortest walking route. Since 98.1% of the accidents took place within eight miles of the pedestrian's residence, for convenience, all accidents (i.e. 1.9%) occurring beyond this eight mile limit were excluded, because the latter showed wide scattering in distance.

These data are presented graphically in the adjoining Figure One and are grouped as indicated according to the class middles of the unit selected. Distance is measured logarithmically on the abscissa, and the frequency of accidents is measured logarithmically on the ordinate. The best straight line fitted to these points by least squares had a slope of -1.191 ($\pm .265$) or in equation form $\log y - 1.919 \log x - 2.781$ ($P.\ E. \pm .177$).

From these data it is clear that there is an inverse proportionality between the distance that the pedestrian is from his residence and the frequency of accidents.

[3] *Psychological Abstracts,* 24:101, February 1950.

[4] William R. Chandler, "The Relationship of Distance to the Occurrence of Pedestrian Accidents," *Sociometry,* 11:108-10, 1948.

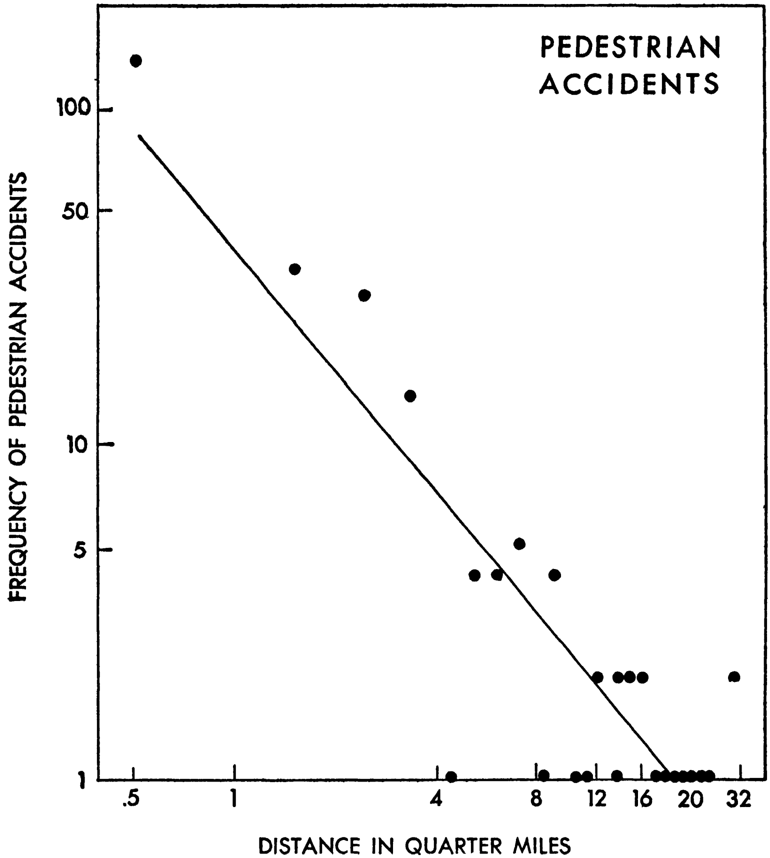


FIG. 1. *Accidents to pedestrians from vehicles of all kinds in relation to the pedestrian's distance from home (Brookline, Massachusetts, 1946 and 1947).*

The reason for this inverse proportionality is not necessarily because of any preference for accidents near home, but instead, because a person is more often near his home and, therefore, has a greater opportunity to suffer an accident there. If we assume that accidents occur at random, then we may conclude that pedestrians are proportionately less likely to take trips of increasing lengths. This conclusion is in line with earlier investigations of others.[4]

1 A paper written under the direction of the University Lectureship of Harvard University.

2 I am grateful to Chief M. Tonra for his cooperation in allowing me access to the files, and to all those in the Traffic Department for their help.

3 I am grateful to the Brookline Engineering Department for allowing me to use their maps and street guides.

[4] W. J. Reilly, "Methods for the Study of Retail Relationships," University of Texas Bulletin, 2944, Nov. 22, 1929. J. Q. Stewart, "An Inverse Distance Variation for Certain Social Influences," *Science*, n. s. 93 (1941), 84; "The 'Gravitation,' or Geographical Drawing Power of a College," *Bulletin American Association University Professors*, 27 (1941), 70; "A Measure of the Influence of a Population at a Distance," SOCIOMETRY, 5 (1942), 63-71. J. H. S. Bossard, "Residential Propinquity as a Factor in Marriage Selection," *American Journal of Sociology*, 38 (1932), 219-244. S. A. Stouffer, "Intervening Opportunities· A Theory Relating to Mobility and Distance," *American Sociological Review*, V (1940), 845-867. G. K. Zipf, "The Hypothesis of the 'Minimum Equation' as a Unifying Principle: With Attempted Synthesis," *American Sociological Review*, XII (1947), 627-650; "The Repetition of Words, Time Perspective, and Semantic Balance," *Journal of General Psychology*, 32 (1945), 127-148.

The following example of a descriptive abstract illustrates how this type of abstract indicates to the reader whether the article will be of interest to him even though it does not summarize the content of the article.

ELECTRON BEAMS STERILIZE FOOD AND DRUGS. E. Alfred Burrill and A. John Gale. *Electronics* 25, 98-101 (1952) Nov.

The importance of the scanning system used with high-energy electron beams to give uniform sterilization of sealed products moving through the beam on high-speed conveyor belts is stressed. A 200-cps scanning circuit to sweep the beam through an 8° arc is diagramed. Elaborate fail-safe provisions are included.[5]

II. DESCRIPTION OF DEVICE AND EXPLANATION OF PROCESS

Since every experiment in pure science and every operation in applied science has its necessary equipment and fixed procedure, much scientific writing takes the form of *descriptions of device* and *explanations of process.* Such descriptions and explanations, dealing with devices, apparatus, objects, and structures and with actions, operations, and procedures, may be the subject of independent scientific papers and are frequently included in longer papers and in textbooks. Descriptions of device and explanations of process, along with directions for handling equipment and performing operations, also constitute much of the subject matter of laboratory and instruction manuals.[6]

A. Definition of Terms

A *process* may be defined as an orderly sequence of events or actions which will, if repeated, produce the same or similar results.

[5] *Nuclear Science Abstracts*, 7(1):5, January 15, 1953.

[6] A highly specialized type of manual is the engineering instruction manual. A typical manual of this kind may be divided into such sections as: general theory, theory of operation, installation instructions, operating instructions, maintenance instructions, and catalog of replacement parts.

Processes may be within man's control, like many processes of applied science, or beyond his control, like geological processes or digestive processes. The *explanation of process* is an expository analysis of such a sequence of actions or events. By breaking down the process into its parts and showing their logical relationships, the writer acquaints the reader with the process and affords him an understanding of its significance. Since many processes involve devices or structures which demand description (see Chapter 9), *description of device* is often a part of an explanation of process. When the steps in a process are stated imperatively as a series of commands, the whole is known as *directions*. Although the *explanation of process, description of device,* and *directions* are distinct forms, they are so often used in combination that they will be discussed together.

B. Writing of Papers of Device and Process

Before beginning an *explanation of process,* the writer must decide whether his purpose is to tell the reader how to do something or how something is done. For example, a paper on the analysis of uranium in sea water may be intended to explore the method of analysis in such technical detail that the properly qualified reader will be able to repeat the process. Yet an explanation of the same process written for the general reader may give only enough information to enable the reader to understand the significance of the process and the nature of the principal steps involved. Similarly, a *description of device*—a description of a radio receiving set, for instance—may stop with making clear the structural principles of the set or may add the detail which will enable the reader to construct it.

In preparing papers of device and process the writer may follow a fairly well standardized plan. If the explanation is to enable the reader to construct the device or carry out the process, all materials must be accurately identified and all measurements exactly given; detailed diagrams will probably also be needed. Such necessary preliminary information as definitions of terms, descriptions of essential equipment, and lists of materials should be given before beginning the explanation of the steps in the process. In explaining these steps the order is determined by the time sequence, but mere regard for time sequence is not enough. The process must be analyzed into its separate parts. Even a simple task such as replacing a plug on an

electric cord consists of a series of distinct steps. A complex process may consist of several stages or phases with different steps in each phase.

Writing a description of a device or apparatus, whether such a description is offered as an introductory part of an explanation of process or as an independent paper, also involves the use of analysis. A description of an electric refrigerator, for example, may begin with the statement that there are three main parts: the motor, the compressor, and the freezing unit. An orderly arrangement of detail in describing a device or apparatus helps to make spatial relationships clear. A description may proceed from the outside in, from front to back, from left to right, or any of these directions in reverse. The use of an analogy may help the reader to follow the description if the structure resembles a ball, a wheel, a figure-eight, or any other well-known and easily visualized form. The operation of the gear-shift lever of a car, for example, is often described by reference to the letter H.

Once the order of details within the description has been established, the next essential is simple and consistent expression. Parallel sentence structure should be used to state corresponding facts. Tense and mood should not be needlessly shifted. The same terms should be used throughout to refer to the same objects and operations. Students are often needlessly afraid of repetition. In an exposition of process, referring to one thing by half a dozen synonyms does not result in pleasing variety but in most unpleasing confusion.

Careful observance of parallelism is particularly important in writing directions since the reader is treated as a participant and not merely as an observer, and each direction given must be stated in the imperative mood. Directions in the imperative may, however, be accompanied by explanatory sentences in the indicative. The second person pronoun *you* is used in addressing the reader, as in the following selection from a series of directions designed to help in the development of study skills.

> 1. Glance over the headings in the chapter to see the few big points which will be developed. This survey should not take more than a minute and will show the three to six core ideas around which the rest of the discussion will cluster. If the chapter has a final summary

paragraph this will also list the ideas developed in the chapter. This orientation will help you organize the ideas as you read them later.

2. Now begin to work. Turn the first heading into a question. This will arouse your curiosity and so increase comprehension. It will bring to mind information already known, thus helping you to understand that section more quickly. And the question will make important points stand out while explanatory detail is recognized as such. This turning a heading into a question can be done on the instant of reading the heading, but it demands a conscious effort on the part of the reader to make this query for which he must read to find the answer.[7]

C. Examples of Papers of Device and Process

The following description of a spectroscope is intended to give the student of spectroscopy an understanding of the instrument. The classification which precedes the description explains the purpose of the spectroscope and its relation to other instruments. The description itself is analytical in form, and the essential parts of the instrument are illustrated by a simple diagram.

Spectroscopes and Spectrographs. Any instrument that can be used to produce a spectrum, visible or invisible, is called a *spectroscope*. Under this general heading instruments are classified according to the means by which the spectrum is observed.

A *spectrograph* produces a photographic record of the spectrum called a *spectrogram*. The word *spectroscope* is sometimes used in a restricted sense to designate an instrument arranged so that the spectrum can be viewed by eye. It will be used in this book only in the broad sense; the term *visual spectroscope* will be used to designate instruments arranged for direct eye observation of the spectrum. *Spectrometers* are so built that an observer can determine wavelengths by reading a scale, which may or may not be calibrated to read directly in microns, millimicrons, or angstroms.

Most spectroscopes contain three main elements: a slit; a dispersing device such as a prism or a diffraction grating to separate radiation according to wavelength; and a suitable optical system to produce the spectrum lines, which are monochromatic images of the slit. A simple spectroscope optical system is shown in Fig. 1.2. The spectrum lines are arrayed along a focal curve where they may be photographed, observed with an eyepiece if visible, or isolated from their neighbors by a second slit. The first method is used in spectrographs, the second in visual spectroscopes, and the third in monochromators.

[7] Francis P. Robinson, *Effective Study*, New York, Harper & Brothers, 1946, p. 28.

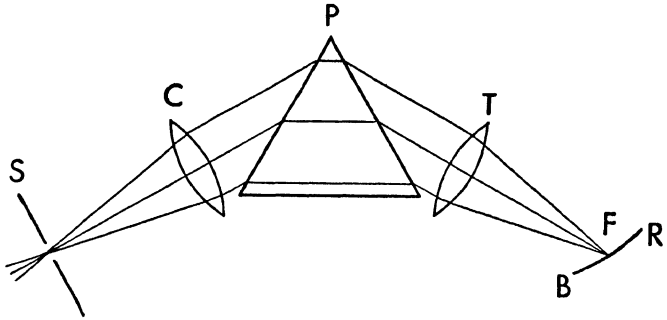


Fig. 1.2. *Optical system of a simple spectroscope.* S, *slit;* C, *collimator lens;* P, *prism;* T, *telescope lens;* F, *curve along which the various parts of the spectrum are in focus;* B, *blue or short wavelength part;* R, *red or long wavelength part.*

Spectrum lines are detected or recorded by various means. Infrared spectroscopes are usually equipped with radiometers, which produce variations in current through a galvanometer and hence vary its deflection. These variations of deflection may be recorded in curves of the type shown in Fig. 1.3 [not shown]. The spectrum can be recorded by this means at any wavelength, but more sensitive methods are used in spectral regions where they are available. Photography is feasible between 15,000 and 10 A. Though sensitive and convenient, photography requires careful control if quantitative results are to be obtained. Fluorescence and phosphorescence methods, combined with visual observation or photography, can also be used between 15,000 and 10 A, with some loss in sharpness of narrow lines. Photoelectric recording has been used between 33,000 A and the short vacuum ultraviolet. In all these cases the 10 A limit is purely arbitrary, since the sensitivity extends on into the region of X-ray spectroscopy.[8]

The following article on the Geiger counter leads the reader effectively from an identification and history of the counter through an explanation of its operation to an enumeration of important uses. Marginal notes are offered here to indicate the relation of the paragraphing to the general plan.

Preliminary definition of radiation

The concept of radiation, keystone of modern physics, is bewildering indeed to the layman. Here lies that strange, unreal world where matter and

[8] George R. Harrison, Richard C. Lord, and John R. Loofbourow, *Practical Spectroscopy* (Copyright 1948 by Prentice-Hall, Inc., New York); pp. 7-10. Reprinted by permission of the publisher.

energy merge, where unseen light may burn and kill deep under the skin, where voices are carried on nothingness at fantastic speeds. The physicist talks of X-rays, of radio waves, of cosmic rays, of radiation from uranium and atomic bombs. What does he mean?

Briefly radiation is the release and transmission of energy by changes in the atom or the atomic nucleus. Some changes result in emission of pure energy, such as light. At other times, as in the case of radium, actual fast-moving particles are thrown off.

History of the Geiger counter

Nearly 40 years ago, Hans Geiger, a German student of England's Lord Rutherford, invented a mechanism to detect radiation. The Geiger counter, which can reveal the presence of a single, tiny electron, is science's most sensitive instrument. Moreover, it is fast becoming one of the most important tools of science, a vital aid to the nuclear physicist and of increasing medical and commercial value.

Principle of operation

High energy radiation, whether from X-rays, radium, atomic bombs or cosmic rays, is able to ionize or charge electrically neutral gas molecules either directly by simply knocking off electrons or indirectly. The electrons carry a negative charge, and the molecules from which they are separated become positively charged ions. This resembles the photoelectric effect of visible light which is also radiation of relatively low energies. The ionization property is used in the Geiger counter to detect and estimate the intensity of radiation.

Physical description

The counter consists of a vacuum tube in the form of a negatively charged metal cylinder through which a positively charged wire is stretched. The difference in potential between wire and cylinder may run from 250 to 5000 volts. Radiation, permitted to enter the tube through a window, ionizes the small amount of gas left in the tube.

Mechanism of operation

The positive ions move toward the negative metal walls; the free electrons rush to the wire. The motion produces a pulse of electricity large enough to be measured. Upon reaching the wall

the ions are again neutralized, the pulse dies away and the counter is sensitized for the next ray or particle. In a "slow" counter the electric pulse persists from one-tenth to one-hundredth of a second following the entrance of the radiation; in a "fast" counter it lasts only one ten-thousandth of a second.

Uses The feeble electric discharge generated in the process may be amplified to operate a mechanical counter, to mark an oscillograph or to click in a pair of head phones. The significance of the number of pulses per second depends upon the design of the instrument, the probable amount of radiation absorbed by the walls and the constancy and location of the source of radiation with respect to the counter.

We live constantly bathed in radiation of all kinds, so that a counter operates continually at a fairly constant rate. In the vicinity of a source of radiation, such as an X-ray machine or a capsule of radium, the number of pulses recorded goes up markedly. The counter is a super-snooper. An atomic bomb explosion, even on the other side of the world, releases enough radiation to increase its activity. Increasing use of radioactive tracers in medicine, scientific research and industry has given it many new jobs. Foundries use it to inspect castings and forgings, petroleum companies for logging of oil wells, hydro-electric plants for estimating the volume of flow through the turbines.[9]

The next two examples are concerned with processes. In the first selection the steps in the process of wool stapling are presented in direction form. The numbered directions are accompanied by an opening and concluding paragraph of explanation.

In the stapling of wool, it is necessary to get some idea of the distribution of fiber lengths as well as the average staple. In the case of wool, also, we have longer fibers which are easier to handle singly or in small numbers. Wool stapling, therefore, consists of laying out all the fibers from a sample on a proper background in the order of their lengths. The steps in stapling a sample of top are as follows:

[9] *Power Plant Engineering,* 51:101, October 1947.

1. On a piece of black velvet, mounted rigidly on a board, draw a chalk line for a base.
2. Square up the end of the top by pulling out the loose fibers.
3. Grip the square end of the top between the thumb and forefinger of the left hand and pull out a tuft of fibers free from the rest of the top, being careful not to break the fibers. This new end will be long and tapering.
4. Transfer the square end to the right hand and, very slightly, twist together the longest fibers in the tapering end.
5. Place the top of the longest fibers on the chalk line, hold with one finger of the left hand and slowly pull the main tuft away with the right hand, at right angles to the base line. The fibers should cling to the black velvet.
6. Repeat with the next longest fibers, alongside of the first set, and continue until all the fibers are on the velvet. Try to get a uniform density of fibers throughout.

For ordinary mill routine, the average length of staple is determined by placing a rule parallel to the base line and in such a position that there is as much long fiber above as short fiber below. This average length is read, also the longest length. For a somewhat more accurate determination of average staple, a tracing of the fiber layout may be made. The area, measured with a planimeter, divided by the length of the base would then be the average staple. A still more accurate method would be to take all fibers between certain length measurements and weigh them, repeating this operation for the same length interval all along the array. The average length of each group would then be multiplied by the weight of the group. These products added up and divided by the total weight of the sample would give the average staple.[10]

The concluding example in this section is an explanation of process taken from an article dealing with procedures used in tests of commercial tires for treadwear.

Procedure of Test

Weight Method. The procedure is essentially the same as that used by Roth and Holt. The tires for test are mounted with inner tubes on appropriate rims. The mounted tires are weighed on an equal-arm balance. The main knife edges of the balance rest on tungsten-carbide inserts in order to avoid changes in sensitivity, which is 0.5 gram or less. However, all weighings are made to the nearest gram. The weighings are made by the constant sensitivity method, in which a tare

[10] John H. Skinkle, *Textile Testing*, Brooklyn, Chemical Publishing Company, Inc., 1949, pp. 36-37.

heavier than the heaviest mounted tire is placed on one pan of the balance and the tire assembly is placed on the other pan together with sufficient weights to balance the tire. The balance point is detected by the method of swings. A periodic determination of the rest point is made by checking the tare with an equivalent known weight.

In the early tests, all weighings were made with the tires inflated. Corrections were made in the inflation pressure for changes in the ambient temperature. Since an error of ¼ pound per square inch in the adjustment of the inflation pressure results in an error of about ⅔ gram in the weight of a 6.00-16 tire to about 3 grams in the weight of a 11.00-20 tire, recent tests have been made by making all weighings with the tires deflated. In these tests, the valve core was removed to be sure that the air in the tube was at atmospheric pressure. The compressed air for inflation of the tires was filtered to remove any dirt, oil or water droplets. Before inflating the first tire, the air line was opened to blow out any condensate that might have accumulated.

Before test, passenger car and light truck tires are dynamically balanced and heavy truck tires are statically balanced. The weighings are made with the balancing weights in place. A check is made before each weighing, however, to see if any balancing weights were lost. Also, the mass of the balancing weights on each tire is determined by weighing the tire assembly before and after balancing. Thus, it is possible to determine the weight of the tire in case one or more of the balancing weights are lost.

The vehicles are loaded before each test with cast iron weights in such a manner that the same load is on each wheel. The load in most tests is the maximum recommended load of the Tire and Rim Association, Inc. Because of the limiting minimum weight of the empty vehicle, small sizes of tires are overloaded but in no case more than 15 per cent. The alignment of the wheels and the condition of the brakes are examined and any necessary corrections made prior to the test. During the course of a test, every effort is made not to disturb the alignment of the wheels, the condition of the brakes, or any other mechanical condition of the wheels. In this connection, the alignment of the wheels is checked before each period to verify that it has not changed.

The tires are placed on the vehicles in accordance with the design of test. The vehicles in each test are operated in a convoy. During each period of slightly more than 500 miles, each tire remains on the wheel to which it is allocated. At the end of the period, the tires are removed from the vehicles, stones and other foreign particles are removed from the treads, and dirt on the tires is removed by washing with water. If the tires become contaminated with road tar, it is removed with gasoline. After washing, the surplus water is removed with compressed

air and the tires are allowed to dry at least 16 hours before they are deflated and weighed.

As a control, the spare tire on each vehicle is treated in the same manner as the tires being tested. The weight of the spare tire remains essentially constant except when most of the period is wet (transient showers do not cause any difficulty). Even under these conditions, the weight of the spare tires remains fairly constant when mounted on full drop-center rims. However, tires mounted on truck rims increase in weight indicating that water has gotten into them. When this condition occurs, the tires are deflated and dried in a room maintained at 100° F. until the spare tires return to the correct weight (generally 48 hours). The drying is sometimes accelerated by passing filtered compressed air between the rim and the tire. This difficulty in wet weather is the principal disadvantage of the weight method. The following procedure for conditioning tires before weighing has, however, been found to eliminate the principal difficulties generally encountered in wet weather: After the tires are removed from the vehicles and cleaned at the end of each test period, they are deflated and placed in a room maintained between 100° and 110° F. for a period of 40 hours. If the roads were wet during the test period, filtered compressed air is injected through the valve hole or slot in the rim during the drying period. Before the tires are weighed initially, they are also placed in the drying room for a period of 40 hours.

If a puncture occurs on the road, the mileage is recorded and the tire is replaced with the spare until the vehicle returns to the testing station where the object causing the puncture is removed. The punctured tire after complete deflation is weighed. The tube is removed and repaired or replaced depending on the extent of the damage. After remounting the tire with the valve stem of the tube in the same relative position as before the puncture, the assembly is again weighed. The difference in weight before and after repair is applied as a correction in determining the total weight of the tread. When it is necessary to replace the tube, the tire is rebalanced and appropriate corrections are made for any change in the mass of the balancing weights. If a tire is damaged beyond repair (which did not occur in any of the tests in this paper), a duplicate tire is substituted for the one that failed and the test continued; if necessary, the period in which failure occurred is repeated.

After the road test is completed, the remaining tread is removed by buffing to determine the total weight of tread. A specially designed machine is used. It has adjustments for buffing to any tread radius between 6 and 13 inches, to any tread depth on tires between 6.00-16 and 11.00-20 in size, and for centering the different sizes of tires with respect to the buffing wheel. Each tread is buffed to the tread radius

that existed at the end of the road test. The tread is removed in such a manner that the depths of the two outside grooves are equal even though one shoulder may have worn faster than the other during the road test. Buffing is terminated when any one of the tread grooves disappears for 180 degrees around the circumference of the tire. After buffing, the tire assembly is again weighed in the manner previously described and the weight of the tread is calculated from the initial and final weights and any corrections resulting from punctures.

If tires having the same tread design and carcass construction are tested, it is not necessary to buff the tread to determine the comparative treadwear. Since the volume of the tread is the same on such tires, relative treadwear can be determined from rate of wear and density measurements only.

Depth Method. In the tests reported in this paper, the depth of each tread groove was also measured each time that weight measurements were made. Depth measurements were made to the nearest thousandth of an inch at four locations in each groove, spaced approximately 90 degrees apart. Since the bottom of many tread grooves was not smooth, three or more readings were taken with a dial gage at each location. The minimum reading was taken to represent the depth at that point since exploratory tests showed this reading to be the most reproducible. The locations at which measurements were made were marked so that the depths could be measured at the same locations after each period. The values for the depths at the four locations in each groove were averaged. Considerable difficulty was encountered in measuring the depth of the grooves in certain tread designs, and the poorer reproducibility in making depth measurements in these tests than in tests previously reported may be partly attributed to this cause.[11]

III. THE CASE HISTORY

Of all the specialized forms of scientific writing, the *case history* probably makes the strongest appeal to the general reader. The individual instance of a principle or condition—a case of murder, a case of measles, a case of juvenile delinquency, a case of hysteria—has the human appeal which the abstraction lacks.

A. Definition of Terms

In order to understand fully the scientific significance of the case history, the student must understand the relationship between the individual instance and the generalization in the growth of scientific

[11] R. D. Stiehler, G. G. Richey, and J. Mandel, "Measurement of Treadwear of Commercial Tires," *Rubber Age*, 73:202-04, May 1953.

knowledge. First, a general principle or concept is built up from the study of many individual instances or cases.[12] Then a typical case may be taken as illustrative of that principle. In popular usage, and even in uncritical professional usage, the term *case* is often used in referring to the person concerned. Authorities, however, are more restrictive in their use of this term:

> A case is an instance of disease, the totality of the symptoms and of the pathologic and other conditions; a patient is the human being afflicted. One continually finds in medical manuscripts such sentences as "The case had a fever," "Thirty cases were admitted to the hospital" and "The case was operated on." In the publications of the American Medical Association such usages are banned.[13]

Similarly:

> The social worker's "case" is the particular social situation or problem—not the person or persons concerned. For the person, as distinguished from his problem, the term now in general use is "client." [14]

From the time that an individual presents himself for professional assistance his case becomes a matter of record. Prepared blanks or forms are often used in making these records, and laboratory and other special reports are filed with them. When the case records are written up for presentation to a professional society or agency, the paper is known as a *case report.* (See Chapter 11.) A short case report may be a simple summary in narrative form. For a longer report analytical divisions are used, such as the subject's history, family history, physical examination, laboratory examination, etc.

Case history is a general term used to denote an account of a case from its inception to date or to its conclusion. The term *case history* may also apply to a short illustrative summary used for teaching

[12] Recognizing the possibilities in teaching general principles through specific instances, James Bryant Conant in 1947 suggested in *On Understanding Science*, New Haven, Yale University Press, pp. 16-17, that the nature of science be taught by the use of "case histories" or accounts of individual scientific discoveries which illustrate "the tactics and strategy of science." More recently Conant's suggestion has found expression in his book *Science and Common Sense*, New Haven, Yale University Press, 1951.

[13] By permission from *Medical Writing*, by Morris Fishbein, p. 44. Copyright 1948. McGraw-Hill Book Company, Inc.

[14] Mary E. Richmond, *What Is Social Case Work?*, New York, Russell Sage Foundation, 1922, p. 27.

or expository purposes. In introducing a series of case histories, S. W. Ranson has stressed their instructional value:

> An excellent review of anatomic neurology can be obtained by a study of a series of neurologic patients and an attempt to interpret their symptoms in terms of damaged cell masses and fiber tracts. The following brief case histories may serve in lieu of actual patients. Each will be found to illustrate some important facts concerning the organization of the nervous system.[15]

B. Writing of Case Histories

The problems presented in the writing of a *case history* or a case report are those of selection, arrangement, and style. (See Chapters 8, 9, and 11.) Material, however colorful, which does not bear on the scientific interest of the case should be excluded. Even if the account is long enough to justify an analytical arrangement, chronological order should be followed within the divisions. The writer should never interrupt the course of his narrative to go back to relate something that happened previously. The telegraphic style sometimes used in case records is not permissible in case reports or case histories.

Although there is a strong resemblance among case histories, there are also differences among them in both content and presentation. A case may be selected for presentation to a clinical society or journal because of its unusual or surprising features. For purposes of instruction, a typical case is more likely to be chosen. The aim may be the presentation of enough clinical detail to form the basis of thorough study or discussion, which will demand a long and analytically arranged report. Or the aim may be the inclusion of only enough detail to make possible an understanding of the essential or the peculiar features of the case.

C. Examples of Case Histories

The form of the medical case history has had a widespread influence in other areas. The following case history, included by John A. Ryle in *The Natural History of Disease* to illustrate the "manifestations of thyroid deficiency," is in chronological order. It includes

[15] Stephen Walter Ranson and Sam Lillard Clark, *The Anatomy of the Nervous System*, 9th ed., Philadelphia, W. B. Saunders Company, 1953, p. 396.

a brief family history and a fairly detailed account of the patient's illness, the symptoms, the treatment, and the results.

Case 1. Mrs. N——, aged 42, was admitted on 23 February 1923. Her mother died of consumption. She had two daughters living, aged 21 and 19 years. Two other children died in infancy. Twenty-two years ago she had enteric fever. Before this date she enjoyed perfectly good health, but she has never felt really fit since the illness. In 1911 she had pneumonia, and six months later was operated on for appendicular abscess. These two illnesses further aggravated her feelings of unfitness. For 12 years she has noticed gradually increasing muscular weakness, with impairment of memory and slowness of speech. She has also experienced an increasing intolerance for cold, and feels chilly even in summer. In recent years she has been growing fat, though latterly she has again lost weight. She has noticed puffiness of the face and eyelids and dryness of the skin. She never sweats. Recently she has had to give up her household duties on account of weakness. She frequently forgets what she wants to say, and whereas she used to be "sharp-spoken," she is now "very slow." Her hair has been falling. The periods have been irregular. She was sent to Guy's, however, not so much for these general symptoms as for some vague abdominal discomforts, for which she was seen by Mr. Turner. He considered that these symptoms could be sufficiently accounted for by visceroptosis, and was struck by her general condition. He drew attention to the hyperaemic patches on her cheeks, which suggested mitral stenosis. These were a striking feature, contrasting sharply with her rather yellowish underlying pallor. Even more striking, however, was the general heaviness of the features, and the complete absence of any play of emotion or expression in the course of the interrogation. The eyelids were slightly puffy. The hair was dry and coarse, and the outer half of the eyebrows was lacking; the hair-margin had considerably receded. Her voice was monotonous, and her words were uttered slowly. Her latent period in answering questions was longer than normal. The integument of the forehead was thick. The skin was everywhere dry, and the axillary hair was scanty. Her pulse was 64, temperature 97.4°, and respiration-rate 20. The systolic blood-pressure was 135. The blood showed a haemoglobin percentage of 65, and a red cell count of 4,140,-000. The basal metabolic rate was minus 24.7 per cent. Glucose tolerance was, however, normal. It should be mentioned that she had been taking small doses of thyroid while awaiting admission. She was treated with thyroid in the form of Tab. Thyroid (B. & W.), and seemed to do best on a dose of gr. 2 thrice daily. This represents only about gr. 1½ of dried thyroid in the day. She improved steadily, and a few months later, excepting for a slight tendency to dizziness, had lost all her symptoms. Her colour had improved remarkably. In figure she

became slim and sprightly. Her face and expression were happy and vivacious.[16]

Out of the vast number of case histories in psychosomatic medicine, psychiatry, and psychology, it is impossible to select one which is typical. The example included here from the writings of Sigmund Freud has not been chosen with any thought of implying a judgment on the Freudian theory and practice of psychoanalysis. It has been selected rather because the interest which the ideas of Freud aroused was undoubtedly due in part to the literary skill with which he explained his theories in terms of his case studies.

In this instance an account of the previous history of one of Freud's patients is offered as evidence in support of Freud's theory of the dream as a wish fulfillment, and the introduction and arrangement of the account are governed by this purpose.

Yet another dream of a more gloomy character was offered me by a female patient in contradiction of my theory of the wish-dream. This patient, a young girl, began as follows: "You remember that my sister has now only one boy, Charles. She lost the elder one, Otto, while I was still living with her. Otto was my favourite; it was I who really brought him up. I like the other little fellow, too, but, of course, not nearly so much as his dead brother. Now I dreamt last night that I *saw Charles lying dead before me. He was lying in his little coffin, his hands folded; there were candles all about; and, in short, it was just as it was at the time of little Otto's death, which gave me such a shock.* Now tell me, what does this mean? You know me—am I really so bad as to wish that my sister should lose the only child she has left? Or does the dream mean that I wish that Charles had died rather than Otto, whom I liked so much better?"

I assured her that this latter interpretation was impossible. After some reflection, I was able to give her the interpretation of the dream, which she subsequently confirmed. I was able to do so because the whole previous history of the dreamer was known to me.

Having become an orphan at an early age, the girl had been brought up in the home of a much older sister, and had met, among the friends and visitors who frequented the house, a man who made a lasting impression upon her affections. It looked for a time as though these barely explicit relations would end in marriage, but this happy culmination was frustrated by the sister, whose motives were never completely ex-

[16] John A. Ryle, *The Natural History of Disease*, 2nd ed., Oxford, Oxford University Press, 1948, pp. 368-69.

plained. After the rupture the man whom my patient loved avoided the house; she herself attained her independence some time after the death of little Otto, to whom, meanwhile, her affections had turned. But she did not succeed in freeing herself from the dependence due to her affection for her sister's friend. Her pride bade her avoid him; but she found it impossible to transfer her love to the other suitors who successively presented themselves. Whenever the man she loved, who was a member of the literary profession, announced a lecture anywhere, she was certain to be found among the audience; and she seized every other opportunity of seeing him unobserved. I remember that on the previous day she had told me that the Professor was going to a certain concert, and that she too was going, in order to enjoy the sight of him. This was on the day before the dream; and the concert was to be given on the day on which she told me the dream. I could now easily see the correct interpretation, and I asked her whether she could think of any particular event which had occurred after Otto's death. She replied immediately: "Of course; the Professor returned then, after a long absence, and I saw him once more beside little Otto's coffin." It was just as I had expected. I interpreted the dream as follows: "If now the other boy were to die, the same thing would happen again. You would spend the day with your sister; the Professor would certainly come to offer his condolences, and you would see him once more under the same circumstances as before. The dream signifies nothing more than this wish of yours to see him again—a wish against which you are fighting inwardly. I know that you have the ticket for to-day's concert in your bag. Your dream is a dream of impatience; it has anticipated by several hours the meeting which is to take place to-day."

In order to disguise her wish she had obviously selected a situation in which wishes of the sort are commonly suppressed—a situation so sorrowful that love is not even thought of. And yet it is entirely possible that even in the actual situation beside the coffin of the elder, more dearly loved boy, she had not been able to suppress her tender affection for the visitor whom she had missed for so long.[17]

The case history as used in social work has been defined as "a body of personal information conserved with a view to the three ends of social case work, namely, (1) the immediate purpose of furthering effective treatment of individual clients, (2) the ultimate purpose of general social betterment, and (3) the incidental purpose of

[17] Sigmund Freud, *The Interpretation of Dreams*, translated by A. A. Brill, 3rd ed., London, George Allen & Unwin, Ltd., 1932, pp. 156-58. Used with permission of the publisher.

establishing the case worker . . . in critical thinking." [18] Because of the day-to-day character of the social case worker's relationship with the client, social case records involve a great deal of detail. Such records are difficult to keep accurately and difficult to summarize in narrative form.

The opening sentence of the following example of a case history is a succinct statement of the point which the authors wish to illustrate through the use of the account of this case. The arrangement here is more analytical and less chronological than that of the preceding examples. In order to give a complete background of this child's case, it was necessary first to consider her parents as individuals, then to offer an account of their marriage. The concluding paragraph sums up again the significance of the case—this time in specific terms—and suggests a possible approach to adjustment.

> The case of Anna Boone, a little girl of seven, illustrates with great clarity how the father's attempt to give his daughter security ended in disaster because it robbed his wife of hers. The early history of Anna's father was unusually free from serious disturbances. As the youngest son of a prosperous business man, Edward's childhood was comfortable and pleasant in material ways, and essentially secure emotionally. The elder Mr. Boone was very fond of Edward and they were companionable in many ways. In spite of a quick and rather violent temper Mr. Boone was lenient with his children and particularly so with this last child of his. Though the younger Mr. Boone returned his father's affection, he told the Bureau worker that he was fondest of his mother. She is described as an intelligent woman, interested in club activities, albeit at the same time a devoted mother.
>
> All of Edward's brothers became successful business or professional men. Edward, on the other hand, after finishing the eighth grade, refused all offers of further schooling and, after a short course in business college, entered his father's office. The entire family, while expressing a fondness for and loyalty toward this youngest brother, nevertheless look upon his economic status as a mark of failure. Their attitudes toward his changing jobs and business reverses have added to his feeling of inadequacy.
>
> Edward remained single until the age of forty. His marriage to a girl ten years his junior was a terrific shock to his family, the more

[18] Ada Eliot Sheffield, *The Social Case History*, New York, Russell Sage Foundation, 1920, pp. 5-6.

so as they considered her of inferior stock and unworthy of becoming one of them.

In contrast to the history of satisfying childhood experiences in which Edward grew up, the background of his future wife was predominantly negative in value. Ruth Morse's father was an undemonstrative, nervous but kindly man who played little part in her life. Her mother was a delicate woman who died in childbirth when Ruth was but five years old. Mr. Morse, finding himself with a small daughter to care for, soon remarried. The second Mrs. Morse was a vigorous woman of much common sense, but severe and unyielding. She had two daughters of her own by Mr. Morse and though she strove for impartiality, Ruth says she "always felt a difference." There were never any open breaks. Ruth was always on excellent terms with her stepmother and half-sisters even after her marriage to Mr. Boone. Nevertheless, there is ample evidence of her childhood unhappiness. She had frequent crying spells, cried much in her sleep, and was looked upon as generally "queer." Mrs. Morse did not allow her to play on the street but kept her indoors to help with the care of the children.

Ruth brought to her marriage the full measure of her depriving experiences, great insecurity, and a deep-seated need to find a protective, understanding "parent-person" in her husband. From the first, her immaturity and unreadiness to assume responsibility were apparent. She had hated housework as a girl and her first reaction after marriage was to let down completely and play invalid for three months. Her untidiness, poor judgment, and constant complaints were further evidences of her childishness. Mr. Boone was able for some time to treat her as she wished to be treated. He had a pleasant manner, a self-assured air in which she could rest confident, and a flattering repentance after one of his outbursts of temper. As a young cousin of his told the Bureau worker one day, "he would die to protect his wife from injury." This devotion of his, given in such a paternal spirit, could not but be utterly satisfying to a woman who had had almost no demonstration of affection in her entire existence.

This condition of satisfied self-centeredness could not be permanent however much Mrs. Boone wished it. Her pregnancy was an immediate threat to her. She felt badly all the time, and though she talked about wanting a baby her unconscious resistance came through at night for she cried constantly in her sleep. Just as she reacted in former days to responsibility thrust upon her by the death of her mother, the advent of a stepmother and baby half-sisters, so now she responded to the necessity of giving up her dependency upon her husband in order to be a parent to their child.

Anna did not thrive in this over-charged emotional atmosphere. As

an infant she lost weight, refused to nurse, and cried continually. Her aunts say she was "disagreeable from infancy," that this trait was apparent when she was only a week old. It is easy, however, to recognize in the baby's fretfulness and irritating ways an inevitable response to the mother's resentment and the insecurity to which Anna was exposed in consequence.

Mr. Boone from the beginning played quite a part in his young daughter's life. His security and consequent ability to take the father role towards his wife enabled him to assume it with Anna also. Had Mrs. Boone been able to accept motherhood, Mr. Boone's attention would have been a most satisfying and constructive experience for Anna. As it was, it contained little of a satisfying nature because by experiencing her father's love she aroused her mother's antagonism. Instead of gaining security with both parents as is every child's prerogative, Anna had none with her mother and was given to feel that she had no right to any with her father.

As Mr. Boone continued to dress the baby, play with her, and be demonstrative in his affections, Mrs. Boone found it more and more difficult to hide her jealousy. It manifested itself at times more subtly, at times quite crudely. She was careless about the child's sleeping hours and diet though she exhibited anxiety over Anna's undernourishment and fatigability. When Anna was difficult to manage, Mrs. Boone threw up her hands, said she was impossible, and left the child to her own devices. Occasionally Mrs. Boone went so far as to predict that she would go insane because of Anna; or to blame her nervousness and wrecked spirits on the child's behavior. Her complaints of ill-health and bids for sympathy were of course nothing but thinly veiled attempts to regain the center of the stage, to rebuild her lost security.

Since much of the history came from the mother, the record of her unwise handling is rather incomplete. On the other hand, not only from Mrs. Boone, but from all other adults as well, come full reports of Anna's attitude toward her mother, the child's response to the deep-lying feeling of rejection. Everyone talked of Anna's "aversion to her mother," her hatred of being touched—strong evidence that the physical contacts of babyhood had been unsatisfying experiences—her refusal to obey unless the mother couched her requests in certain verbal formulae, her tendency to scold Mrs. Boone like a naughty child, and then her rare softened moments when she would say, "Call me darling and be nice to me and then I'll stop crying."

It is easy to see that here one is deadlocked—the child needs security, so does the mother, and the only one who can give it is the father. Yet his attention to either one of them threatens the other and increases the family problem. One's greatest chance of success lies in an outsider, i.e., a social worker or psychiatrist, who may relieve Mrs.

Boone of some of her emotional burdens, knowing that a degree of self-security alone will make possible her adjustment to her daughter.[19]

IV. THE BOOK REVIEW

The *book review* as it is known in scientific journals is an adaptation of a well-known literary form to the needs and interests of those engaged in scientific work. As a literary form, the present-day book review, usually from about four hundred to a thousand words in length, is something of a hybrid. On the one side it traces its ancestry to the ancient art of literary criticism. On the other, it derives from a more recent antecedent—modern journalism. The book review, according to Joseph Wood Krutch, has three minimum tasks—to describe the book, to communicate something of its quality, and to pass a judgment upon it.[20] As journalism, the book review should answer the questions suggested by the five W's of news writing—Who wrote the book? When? Where? What is it about? Why is it significant? "The purpose of the honest reviewer," it has been maintained, "should be to tell the prospective purchaser whether the book is, to him, worth what it costs." [21]

A. The Scientific Writer and the Book Review

Scientists are often by virtue of their special knowledge asked to review books on scientific subjects. The concern of the scientific writer with the book review is somewhat different from that of either the professional reviewer or the literary critic. The scientific writer's first concern is naturally with the usefulness, interest, and merit of new books in his field, not with the tenets of literary criticism or with aesthetics.

Conventional book reviews, including practically all of those which appear in scientific publications, follow the principle that a composition should have a planned beginning, middle, and end. While these parts have no formal division in the book review, they provide a general description and characterization of the book, a discussion

[19] Porter R. Lee and Marion E. Kenworthy, *Mental Hygiene and Social Work*, New York, The Commonwealth Fund, 1929, pp. 33-37.

[20] Joseph Wood Krutch, "What Is a Good Review?" *Nation*, 144:438, April 17, 1937.

[21] E. H. McClelland, "Reviewing of Technical Books—the Minimum Requirements," *Journal of Chemical Education*, 25:380-82, July 1948.

of particular features, and an evaluation. The text of the review is preceded by a formal bibliographical heading which gives the title and author of the book and such information as the number of pages, the publisher, the place of publication, and the price.

The opening paragraph or two of the review indicates the category to which the book belongs—anthology, handbook, biography, field manual, or the like. The reviewer may further characterize the book by indicating its purpose, scope, and length, and by describing the treatment as popular, semitechnical, or technical. He may identify the author and point out his particular qualifications or relationship to the subject. This opening section of the review may include a preliminary evaluation of the book, with reference to any notable features such as unusual illustrations.

Following this initial characterization of the book, the reviewer uses the next few paragraphs to discuss those aspects of the book which, in his opinion, merit special attention and to offer evidence for his evaluation. Quoted phrases may be woven into the review, or longer passages may be quoted to give an idea of the author's style, treatment, or approach.

The review ends with an evaluation of the book in terms of its purpose. Such an evaluation is most useful when it stresses the book's special contribution, mentioning such features as indexes and bibliographies, and points out any marked limitations. The validity of the reviewer's evaluation should be apparent from the evidence which he has presented in the review.

Book reviews may be considered *reportorial* or *critical*, according to whether the emphasis falls on giving information about the book or on evaluating it. The terms *critical* and *criticism* are understood, of course, to include both favorable and unfavorable judgments. Reviews in general periodicals are often more *impressionistic* in style than those in scientific journals. Occasionally a *tangential* review will depart from the subject of the book to discuss a topic which the book suggests to the reviewer.

B. Examples of Book Reviews

The book reviews which close this chapter illustrate the different types of reviews. The first review is predominantly *reportorial* since

it gives a great deal of information about the book with a minimum of critical comment.

A HISTORY OF MEDICINE, by Henry E. Sigerist. Vol. I: Primitive and Archaic Medicine. Publication No. 27, Historical Library, Yale Medical Library (Oxford University Press).

THE BOOK here reviewed is the first of a projected series of eight volumes on the history of medicine which Henry E. Sigerist has retired to Switzerland to prepare, on the basis of the studies of a lifetime. It is encyclopedic in scope and specialists in particular fields may differ with regard to the significance of, say, some special ceremony in a particular Indian tribe. On the whole, however, there can be no question of the soundness of the conclusions drawn, and each chapter is provided with exhaustive references.

The first two-fifths of the volume is devoted to a broad and illuminating discussion of the basic principles involved, of the problems and methods of medical history, of the incidence of disease in time and space, of primitive medicine, attitudes toward the sick, and the place of the "medicine man" in the more primitive civilizations. Sigerist demonstrates that "there are no sharp borderlines and that in the mind of primitive man, magic, religion, and medicine constitute an inseparable whole." He points out that "it is an insult to the medicine man to call him the ancestor of the modern physician. He is that, to be sure, but he is much more, namely the ancestor of most of our professions." And it is fascinating to see how in the primitive arts of healing, the application of empirical science often played a part, as in the discovery of inoculation against smallpox, introduced with the backing of Cotton Mather in Boston in 1716, as a result of information received from one of his Negro slaves.

The last three-fifths of the book is devoted to the development of medicine in Ancient Egypt and Mesopotamia. Sigerist gives us a brief but vivid description of the geographical setting of each of those two great civilizations, of their social and economic conditions, their labor and recreation. In Egypt the scientific element looms large in the empirical-religious-magical art of healing. At the very dawn of history we find two theoretical treatises dealing crudely but with considerable acumen with the basic principles of physiology and pathology. In Mesopotamia, the religious and magical elements were stronger. It is understood that the next book will present a somewhat similar contrasting picture of ancient medical thinking in India and Greece.

Judged from its first volume, Sigerist's work will interest a circle much wider than the medical profession. It is *about* medicine; but it

is history. It is a substantial contribution to our knowledge of the human mind and the ways in which that mind functions in the creation of a social order.[22]

—C.-E. A. Winslow

The second example offers evaluation supported by evidence and is thus a *critical* review. The review follows the not unusual practice of treating together two or more books on related subjects.

From Cave Art to Contemporary Graphic Art [23]

From Cave Painting to Comic Strip. Lancelot Hogben. (288 pp., 211 illus., 20 color plates. Chanticleer Press, New York, 1949.)
Profile Art. R. L. Mégroz. (xii, 131 pp., 140 illus., 60 plates, Philosophical Library, New York, 1949.)

Although very different in purpose, these two books are reviewed together because they are largely picture books that cover a similar time span, from prehistoric cave art to contemporary graphic art. Their greatest, and only real importance for the anthropologist resides in their 332 illustrations. In both books are frequent illustrations of value that are not often reproduced and are difficult to find.

For those acquainted with Hogben's *Mathematics for the Million* and *Science for the Citizen,* it should be said that his present book is again a popular exposition, brilliantly written, of a subject of the first importance. The sub-title, "A Kaleidoscope of Human Communication," makes clear the content of *From Cave Painting to Comic Strip.* Techniques of "human communication" are traced from prehistoric cave painting, through the invention of the calendar, alphabet, and computation systems, to the development of printing, graphic representation, photography, and, finally, the comic strip, movies, radio and television. The major historical facts are usually presented accurately, but in most cases without documentation, in keeping with Hogben's often declared disdain of "cloistered" scholarship. Throughout this book, in fact, there are constantly recurring minor motives made up of his favorite convictions, such as the importance of the fight against illiteracy and the role standardization should play in it, the necessity for world government, so that mankind may survive, and the great importance of visual education in bringing about a world where ideas can be interchanged understandably. These ideas finally emerge as a major theme in the concluding and most important chapter of the book. No one can deny the urgency of the ideas that bear upon the present state of the world. And no one would deny that popularization

[22] *New Republic,* 125(13):19, September 24, 1951.
[23] *American Anthropologist,* 53(3):403-04, July-September 1951.

is important, if rooted in solid scholarship. But the blending of facts, hypotheses, and suppositions is dangerous and undesirable, even if in support of worthy ideals.

Profile Art has, perhaps, less to recommend itself to the anthropologist. It is essentially an art book in which Mégroz discusses in an interesting but discursive and generalized manner the appearance of profiles or silhouettes or outlines in the art of various eras from that of the cave dweller to that of contemporary man. There is no clear-cut distinction between profile, silhouette, or outline. They are, in fact, considered as one and the same thing. There is no real subject-matter, aside from a consideration of a selection of examples that are unrelated in purpose or aesthetic motivation. There is furthermore no attempt at a psychological interpretation of the preference in the art of certain periods for strongly marked outlines. The book, however, does bring together a miscellany of important information on the cut-out silhouettes of the eighteenth and nineteenth centuries. In general, the text suggests that the various sections of the book were taken from a larger historical treatise. For example, the chapter headings list Cave Art, Egyptian Silhouettes, Greek Pottery, Ancient and Medieval ornament, and then vault to eighteenth century shadow painting. The four chapters on shadow painting or cut-out silhouettes are certainly the most important in the book. But the conclusions drawn do not succeed in giving any unity or cohesiveness to the discussions. The book could be used effectively, however, for its illustrations and for its discussion of eighteenth and nineteenth century cut-out silhouette art.

—Paul S. Wingert

The third example is also a critical review and shows how the book review pattern may be used in reviewing a motion picture. The reviewer has limited himself to four paragraphs, devoting the first to a critical characterization of the film, the second to subject matter with comments, the third to the usefulness of the film, and the fourth to a final evaluation. The form of documentation used in the heading for a review of a film should be noted.

Guard Your Heart [24]

Guard Your Heart. How the heart works in health and in certain heart conditions. 16 mm. Black and white. Sound. 27 minutes. Produced for the American Heart Association by Bray Studios, 729 Seventh Avenue, New York 19, N. Y. . . .

Like too many "educational" motion pictures, this is an illustrated

[24] *American Journal of Public Health,* 41(9):1143, New York, American Public Health Association, Inc., September 1951.

lecture. It is a good illustrated lecture, but except for brief sequences at the beginning and end, it does not take advantage of the motion picture technique.

In the traditional manner, we find Sam pretentiously doing all the wrong things, an understanding wife who sends him to the doctor, and a lecture by the doctor on the anatomy and physiology of the heart and circulation. Briefly, all too briefly, Sam is seen reforming. The actors play their parts well, the photography and sound are good; the animation is especially excellent. However, well over half the running time is used up in the doctor's talk, apparently on the assumption that if people know what a heart looks like, where it is, and how it and its related blood vessels operate, they will automatically know what to do and what not to do to protect it. Since this is an assumption of dubious validity, the full value of the film will be realized only if it is used as a basis for discussion.

For the beginning medical student or nurse or first aid class, this lecture is useful as any training film could be. For the layman, there is insufficient down-to-earth demonstration of what a person should or should not do to guard his heart. Furthermore the lecture is replete with medical terms like "arteriosclerosis" and "coronary thrombosis," which confuse the layman even though the conditions are beautifully illustrated in the animation.

In a superb and successful effort to convey information, the picture fails to convey knowledge, especially knowledge that might affect behavior. Briefly, one is left with a feeling that if one has a pain in the chest, he had better see a doctor (which is all to the good)—that the heart is a complicated organ which we ought to take care of (which most people already know)—and that we ought not to run for buses or eat our lunches at our desks. Also, seeing the doctor seems to improve one's golf game. It seemed to this reviewer that these simple messages could have been driven home in much less time and that more direct stimuli to action might have been included.

—Homer N. Calver

The reviewer whose approach is more *impressionistic* than that of the writer who adheres closely to conventional patterns exercises considerable freedom in his choice of words and comparisons. His purpose is to let the reader share his impression of the book, and he may accomplish this end by a variety of means, including even parody, satire, hyperbole, or the *reductio ad absurdum.* A review of this type should be unified in tone. A skilled reviewer may maintain the tone through a fairly long review, as does Clifton Fadiman in the selection included here.

Easy Lessons in Science—Horrors! [25]

Ernest R. Trattner's "Architects of Ideas" aims to recount "the story of the great theories of mankind." In its way a creditable job, the book would have seemed more original and been more useful about fifteen years ago, when H. G. Wells, Will Durant, J. Arthur Thomson, and others were leading us, so many innocent Daniels, into the outline's den. Since those pleasant days we have absorbed a great deal of superficial scientific information about profound scientific truths. A reading body that has digested Eddington and Jeans, Hogben, and Bell, Wells and Huxley may not be entirely satisfied with Mr. Trattner's *réchauffés.* It may listen with some apathy to his hooray-for-the-scientific-spirit cheerleading. I would guess that the furious rush for a book like Einstein and Infeld's "The Evolution of Physics" proves we no longer need to have our science cut up for us by Nursie.

Specifically, Mr. Trattner's chapters on Copernicus, Darwin, Marx, Pasteur, Freud, and Einstein have two strikes on them, simply because the more basic doctrines of these figures have by this time become pretty familiar to those who read at all seriously. But, to be perfectly fair to Mr. Trattner, how much do you know about Hutton, who laid the foundations of modern geology? How much about Count Rumford, that Renaissance personality born out of his time, who demonstrated heat to be a mode of motion? How much about Huygens and the wave theory of light? How much about Schwann and the other investigators of the nature of the cell? How much about Chamberlin, who, with Moulton, figured out the planetesimal hypothesis accounting for the origin of the earth? Caught you there, eh?

I wish that Mr. Trattner hadn't chosen such a basso-profundo title for his book. "Architects of Ideas" makes you expect more than you actually get. If he had called it "Simple Summaries of Part of the Work of Fifteen Modern Scientists, Their Predecessors, and Their Followers," everything would have been fine and dandy. (Also, he wouldn't have sold a copy.) The fact is that "Architects of Ideas" has only a vague unity. Nor does any principle of selection emerge clearly. We get a chapter on Lavoisier, who analyzed the nature of burning and respiration, but, for example, none on Newton, an incomparably greater "architect of ideas." The chapter on Schwann contains hardly more than a brief comment on Thomas Hunt Morgan, whose theory of the gene will probably entitle him to rank with Einstein and Freud. We get twenty-three pages on the classic theorists of heat without a mention of Josiah Willard Gibbs. Sometimes, in his search for great theories, Mr. Trattner goes quite haywire. He has a chapter entitled

[25] Clifton Fadiman, *New Yorker,* 14(12):72, May 7, 1938.

"Boas: Theory of Man." What *is* a theory of man? Franz Boas would hardly claim that his refutation of the nonsense of racial dominance permits him to set himself up as the author of a "theory of man" in the precise sense that Pasteur was the creator of the germ theory of disease. It's all very confusing.

Mr. Trattner can probably answer all these objections easily, but the place to do so is his preface, where you will find little but amiable generalizations.

Don't run off with the notion, however, that his book is bad. On the contrary, it contains much interesting information about many scientists. It's clearly written and each chapter is reasonably well organized. It could, I think, have been a much better book if Mr. Trattner had thought more highly of the intelligence of his potential audience.

The book review may be described as *tangential* when it departs from the book itself to discuss a subject suggested by the book. The reviewer should not offer a review of this type unless he is confident that it will be acceptable to the publication in which the review is to appear. Asher Byrnes' review of George Sarton's *The Life of Science* is a thoughtful and informed discussion first of Sarton's life work and then of a topic it suggests—the scientist's relation to society. But one must glance again at the heading to recall that the review has anything to do with the 197-page volume which occasioned it.

Genesis of "Progress" [26]

The Life of Science: Essays in the History of Civilization. By George Sarton. New York: Henry Schuman. 1948. 197 pp.

Reviewed by Asher Byrnes

George Sarton is one of the few modern scholars of whom it can be said that he is not only the biggest man in his field, but that he also discovered it in the first place. In 1912 he began the publication of *Isis*, a quarterly journal devoted to the history of science. It is still, under his editorship, the principal periodical devoted to the subject. Subject? Perhaps one should rather call it a movement. Since 1912 the numbers of researchers treading on his heels have increased to such a pitch that no less than four more special journals are required to handle their output. Dr. Sarton also edits *Osiris*, wherein he prints material too lengthy and technical for *Isis*. Another journal, *Annals of Science*, publishes papers dealing with the modern period alone; and a further specialization is provided for by *Ambix*, which is devoted to alchemy and other early chemistry, and by the *Bulletin of the Institute*

[26] *The Saturday Review*, 32(1):15, January 1, 1949.

of the History of Medicine (Johns Hopkins)—the title of which is self-explanatory. This brief periodical list takes no account of the many recent series of books on the history of the sciences, or of separate works. Some of these are of encyclopedic dimensions.

And here again Dr. Sarton shines in the forefront. His "Introduction to the History of Science" is the most encyclopedic compendium of all; its scale is so vast that anyone who looks at the volumes which have already appeared will wonder what the history itself will be like, if they are merely the introduction to it. We are sufficiently familiar with cooperative projects that involve hundreds of scholars. This is one that could take centuries of time. Dr. Sarton illustrates the scope of his conception of the history of science by reminding his readers of the "Acta Sanctorum," the first volume of which appeared in 1643 and which is still in progress; and of the history of French literature, which beginning in 1733 and under the Academie des Inscriptions since 1807, has now reached the fourteenth century. Dr. Sarton's Introduction has also just reached the fourteenth century.

These magnitudes of chronology are more mysterious to the modern mind than our statistics of interstellar space. Perhaps Dr. Sarton's final achievement will be that of making us aware of the dimensions of science itself. In the nature of things it must be greater than the enumeration of the phenomena it has enabled us to control. Science approaches the problem of the unknown through what is already known, and the velocity of its progress is therefore proportionate to the knowledge mastered at any given moment. Dr. Sarton summarizes the process beautifully.

However, there is no pressing reason why the scientist should bear in mind the genesis of the discoveries which are now the data of his field of experiment. His interest in that part of the story is limited by the arduous character of the job in hand. An awareness of lines of inquiry exhausted by similar workers keeps him from repeating their mistakes; a familiarity with inquiries that have partially succeeded shows him, more and more accurately, where the truth lies. But with all these aids he must in the final analysis do his prospecting for himself. When so occupied he stands, from one point of view, upon the shoulders of the scientist who preceded him. From another he strides at the head of the human procession. The first is the workmanlike way of looking at scientific activity; the second is the spectator's. Why the scientist sometimes steps out of character and, beholding his function through both viewpoints simultaneously, fills the air with double-talk about everything on earth and in heaven—this is the particular mystery of the twentieth century.

We have reached the point where relatively small additions to our stock of scientific knowledge may have social effects which are of another order of value entirely. The atom bomb was an evolutionary

development in the laboratories; its social impact was, and continues to be, revolutionary outside. Consequently the scientists who participated in that achievement are tormented by the contrast between the humanistic conservatism of their intentions and the mechanical radicalism of their results. In theory nations which can move or "progress" merely by taking thought, merely by peaceful experiment and investigation, need not shoot one another down to find more room. Nevertheless they shoot or bomb each other with the products of the scientist. He is caught in the middle; winners and losers of our horrible modern wars show an increasing tendency to blame him equally.

Apparently the fundamental humanism underlying his effort, together with his consequent claim for absolute freedom in which to carry on his self-appointed task, has not raised him safely above the political struggles of the hour. Whether he likes it or not he is in them, and up to his neck. The easy way out of this dilemma is to cut his connection with the past of science and with the future projected by it. If he is blamed as a partisan he may as well take the wages of partisanship. He may as well join the party of mechanical revolutionaries who place the highest current value on his research products. Where that party is in power he can serve it as a technician. Where it is not he can adopt its ideology.

Against this abandonment of science, Dr. Sarton, who knows more about its history than any man alive, has raised a barrier of books. The books say that progress in pure science became rapid because the value of discoveries was no longer judged by crowds or determined by those who led them, but was sifted by scientists themselves, by men who, as scientists, were free. By men who were maintained and encouraged in such freedom by the rest of us because we grasped the truth which precedes science itself; as men we are less than what we contemplate, and we are more than what we understand. Perhaps we have to teach this to the scientists again.

The types of papers discussed in this chapter are, with the exception of the book review, among the oldest forms used in scientific writing.[27] Some of them long antedate modern science. Directions appear in the Bible. Case histories in the writings of Hippocrates, dating from the fifth century B.C., describe symptoms recognizable by modern physicians and are mentioned in current medical texts. Still more ancient accounts of surgical cases are to be found in the Edwin Smith Egyptian papyrus, "the earliest known scientific document,"

[27] Examples and analyses of engineering papers from ancient times to the present are given in Walter J. Miller and L. E. A. Saidla, *Engineers as Writers: Growth of a Literature*, New York, D. Van Nostrand Company, Inc., 1953.

which dates from the seventeenth century B.C. and is believed to be a copy of an even earlier treatise.[28] The *Epitome* (1543) of Vesalius was more popular than the longer work, *De Humani Corporis Fabrica,* of which it was a condensation.

These types have not, of course, survived unchanged. Patterns of arrangement have tended to become fixed; exact terms and accurate measurements have replaced the vaguer expressions of earlier times. That these special forms of writing should have survived for so long and are today more widely used than ever is a tribute to their utility.

STUDY SUGGESTIONS

1. Consult a dictionary for the primary meaning of the word *abstract* (verb). Show how this meaning is retained when the word is used as different parts of speech (verb, noun, adjective) and in different contexts (science, law, real estate, art).
2. Select a scientific article of interest to you, read it carefully, and prepare a 300-350 word informative abstract of it, including a heading in the format used in one of the well-known abstracting journals. Prepare a descriptive abstract of the same article.
3. Explain why it is difficult to abstract articles such as reviews which are based on printed sources rather than on experimental study. Find an abstract of a review and show how the abstracter has solved the problem of abstracting such a paper.
4. An article expressing the author's view on a controversial subject is also difficult to abstract. An informative abstract of such an article may, however, be written by using an introductory sentence describing or characterizing the article as objectively as possible, then continuing with the abstract, using such phrases as "is held to be," "are presented," "will, it is believed," to identify the opinions expressed as those of the original author. Write the introductory descriptive sentence for an abstract of a controversial article which you have read recently.
5. Explain why it is sometimes desirable to give a history of a typical case, sometimes of an exceptional case. Find examples of case histories in as many different fields as possible. What differences do you find among them? To what do you attribute these differences? Why do you think each case was selected as a subject for a history?
6. Why do editors object to such expressions as "the case had a fever," "the case was operated on," "the case was indifferent to questions"?

[28] The *Edwin Smith Surgical Papyrus,* published in facsimile and hieroglyphic transliteration with translation and commentary by James Henry Breasted, 2 Vols., Chicago, The University of Chicago Press, 1930.

7. Write a complete set of directions specific enough for the reader to follow, choosing as a subject some relatively simple task, such as replacing an electric light socket, taking an indoor photograph, refinishing an antique chest, testing a car battery, preparing a special solution for laboratory use, using a chemical weed killer.
8. Write an essay of process, aiming at understanding rather than participation on the reader's part and choosing a topic from a hobby or outside interest. The following topics are suggestions: how to use a technical dictionary, how to land an airplane, how a color reproduction of a painting is made, how to make a linoleum block print, how to reduce the size of a drawing, how to prepare and stock a farm fish pond, how a panel of jurors is selected, how an index is prepared.
9. Examine the book reviews in a number of scientific periodicals. How closely do you find that they conform to the conventional reportorial or critical review as described in the foregoing chapter? What is the proportion of reporting to critical comment? Are the criticisms supported by adequate evidence? In what form is the evidence presented?
10. Write a review of a book, exhibit, or lecture which you have recently read, seen, or heard.

CHAPTER 14

THE FORMAT OF THE SCIENTIFIC PAPER

> *I had not time to lick it into form, as a bear doth her young ones.* ROBERT BURTON, Anatomy of Melancholy.

I. PREPARING THE MANUSCRIPT FOR PUBLICATION

The subject of this chapter begins where the creative side of scientific work ends. After research has been completed and the paper reporting the results has been written, there remains the task of preparing the manuscript for publication or for submission to an authorized reader. While this assignment is an exacting one, it has two rewards: the satisfaction of seeing one's work properly presented and the satisfaction of sharing in a tradition of craftsmanship.

The work involved in preparing a paper for publication will seem less burdensome once the writer accepts the idea that in the editorial office the most minute details are important. The sum of consistency in these details gives to the better modern journals their attractive

and distinctive format, and it is the obligation of the contributor to do what he can to maintain this standard. The student, even if his work does not yet merit publication, will gain in the proportion in which he applies professional standards to his own work.

The exact procedure to be followed in preparing a manuscript for publication hinges on two questions. First, what manuscript standards apply to this paper? Second, where will guidance in meeting these standards be found? If the paper is one of the short, informal types, the writer need be concerned only with the usual requirements for any manuscript. If the paper is long and formal, like a thesis or report, it will require also a title page, table of contents, and subheadings; sources and references must be cited in a prescribed form.

Guidance in fulfilling these requirements is usually available in the directions of the instructor, department, or journal to which the paper is to be submitted. Most universities provide direction sheets for departmental work, and most publishers issue style sheets or style manuals which set forth in detail the manuscript form they find acceptable. In the absence of instructions the writer should choose a format which is employed or recommended by journals and textbooks in his field. Copies of comparable theses and journal articles are useful as models.

Style manuals vary in length and coverage. The *Style Manual* of the United States Government Printing Office,[1] which runs to 492 pages, contains 25 sections beginning with "Suggestions to authors and editors" and ending with "Foreign languages." Similarly *A Manual of Style* of the University of Chicago Press, widely used in academic and professional publishing, contains 497 pages.[2] The journal *Industrial and Engineering Chemistry* provides for contributors a sheet covering such matters as "Titles," "References," "Drawings," and "Manuscript Copy." Other journals, such as the British *Biological Reviews,* place instructions to authors on the inner side of one of the covers. One of the most widely known science style books is *The Wistar Institute Style Brief*[3] of the Wistar Institute

[1] *Style Manual,* rev. ed., Washington, D. C., United States Government Printing Office, 1953.

[2] *A Manual of Style,* 11th ed., Chicago, The University of Chicago Press, 1949.

[3] *The Wistar Institute Style Brief,* Philadelphia, The Wistar Institute Press, 1934.

Press in Philadelphia, which publishes journals in the biological sciences.

Much unnecessary confusion results from the attempt of inexperienced writers to find a single rule of thumb which can be applied to the preparation of all manuscripts for all occasions. Instead, the requirements for each manuscript should be determined and the manuscript prepared in accordance with these requirements down to the last capital and comma.

II. CONVENTIONAL STANDARDS OF FORMAT

For the convenience of the reader, conventional standards of manuscript format are summarized here under topical headings. Documentation, in which usage is more varied, is treated in separate sections of this chapter.

A. Manuscript

The mechanics of manuscript preparation are in general the same for all types of papers. Copy should be typewritten and should be sent flat, addressed to the editor. Some editors require that a carbon as well as a first copy be submitted. In sending copy to the typesetter, the author's name and an abbreviated form of the title of the paper may be given on each page, preceding the page number. The following rules should be observed:

1. Use $8\frac{1}{2}$ x 11 inch white paper.
2. Use one side of paper only.
3. Double space except possibly for blocked quotations and footnotes.
4. Number pages consecutively with Arabic numerals in the upper right-hand corner of each page, except the first page, which is numbered at the bottom.
5. Allow margins of an inch and a half at the top and left of the page and at least an inch at the bottom and right.
6. If footnotes are used (see Section IV of this chapter), follow one of these practices: (a) place footnotes at the bottom of the page, separating them from the text by a one-inch horizontal line or by a line extending from left to right margin; (b) insert the footnote in the manuscript immediately following the passage to which it refers,

using lines before and after the footnote to separate it from the text; (c) place explanatory footnotes at the bottom of the page and all others in consecutive order at the end of the chapter or article to which they apply. If the appearance of the finished manuscript is important, as in typed theses, the first practice is usually considered preferable. If the manuscript is to be published, the second practice may be preferred since it facilitates the handling of footnotes for the typesetter. Sometimes editorial or academic instructions may recommend the third practice as being more practical for other purposes.

B. Title Page

Most university departments prescribe a form for the title page of a thesis. Some journals also have a set form, including such items as the academic or professional connections of the author, and perhaps requiring that the number of figures or plates in the article be stated immediately after the other items in the heading. In the absence of special instructions, the title page should include the complete title of the paper, centered and in capitals; below it the name of the author or authors; and at the bottom of the page the institution at which the work was done and the date. (See Chapter 12.)

C. Table of Contents

Theses, reports, and some research papers have a table of contents on a separate page immediately following the title page. If numerous illustrations are used, they may be listed in a separate table. If a paper has been prepared according to a well-planned analytical outline, the preparation of a table of contents presents no difficulties, since the main headings in the outline become the main items in the table of contents, and the subheadings in the outline the subordinate items. The main headings in the table of contents may be numbered with Roman numerals at the left; Arabic numerals on the right indicate the page numbers. Both the Roman and Arabic numerals are aligned on the right-hand side. Subheadings in the table of contents are usually indicated merely by indentation, not by letters of the alphabet. In typewritten theses the page numbers can be inserted in the table of contents as soon as the final copy is typed, but in published work not until the page proof is available. The following ex-

ample shows an extended table of contents. An example of a short table of contents appears in Chapter 12, p. 286.

TABLE OF CONTENTS [4]

[4] Frederic R. Veeder, *The Development of the Montana Poor Law,* Chicago, The University of Chicago Press, 1938.

D. Subheadings

If a paper has a table of contents, headings corresponding to those in the table of contents appear in the body of the paper. Even if a paper has no table of contents, the divisions of a paper of any length are usually marked by one and sometimes two or three ranks of headings. Headings of the first rank are sometimes in capitals and centered. Headings of the second and third ranks are often italicized, or underscored, with the first word or the individual words capitalized as in a title. The second rank may be centered and the third placed at the left either above the succeeding paragraph or "run-in" with the first sentence of the paragraph. If no third rank is used, the second rank is sometimes placed at the left. In short papers, sections may be separated by spaces with no topical headings, but this practice is more usual in literary than in scientific or technical work.

E. Quotations

Most scientific papers contain very little quoted matter. In reports of original research second-hand material is kept to a minimum, and since emphasis is on the facts rather than on the wording, such material is summarized rather than quoted. Sometimes a portion of a sentence may be quoted to show another author's terminology or phrasing of a concept. In more general types of scientific papers, quotations are used more frequently than in research reports, although much less frequently than in the humanities.

The usual double quotation marks are used for short quotations. When a quotation of more than a sentence (or as it is sometimes put, more than three printed lines) is used, it is blocked rather than enclosed in quotation marks. In typed manuscript a blocked quotation is indicated by single-spacing and indentation of about an inch at both margins. In printed matter, smaller type may be used in addition to or occasionally in place of the indentation. When a quotation is blocked and set off in this way, no quotation marks are used except those which appear in the original. The blocked quotation has the great advantage that any quotation marks in the original may be retained without the awkwardness of alternating single and double quotes. Permission must be obtained to use prose quotations of more than fifty words or poetry quotations of more than two lines from copyrighted material.

F. Illustrations

Since illustrations are important in scientific and technical work, the style sheets of scientific journals and publishing houses include special instructions—often elaborate—for their preparation. The reproduction of illustrations is expensive, and changes in the usual procedure are not always possible; hence, the writer who plans to use illustrations should familiarize himself with the specific requirements of the publisher. (See Chapter 15.) If a drawing or other illustration is reproduced from any source, permission must be obtained and the source acknowledged by a suitable credit line.

III. THE USE OF DOCUMENTATION

The term *documentation* refers to the means which authors employ to cite their references and sources. While means of documentation include the use of appendixes, bibliography, and footnotes, the principal variations of form occur in bibliography and footnotes.

A. The Purpose of Documentation

The many variations in the handling of bibliography and footnotes among journals and different areas of research should not be allowed to obscure the fact that fundamentally the purpose of all documentation is the same. In essence the documentation of a paper is the presenting of the *documents* in the case. In a court of law "documents"—in a strict legal sense: letters, statements, affidavits—may be presented as evidence. In a more general sense "documents" comprise all the sources—"any writing, book, or other instrument conveying information" [5]—upon which a writer bases his conclusions or which support his position. The very fact that scientific knowledge is cumulative makes it imperative that the scientific writer in presenting new results make clear the basis of his work. He must, through citations of any sources used, give due credit to his predecessors.

The growing recognition of the importance of documentation is apparent in the increasing frequency with which the word *documentation* is used in current writing. In a review of the book *One Thousand Americans,* the importance of its documentation is discussed at some length.

[5] *Webster's New International Dictionary.*

> The reader is tempted, again and again, to lay the book down—to dismiss it as just one more violent and sensational assault upon vested interests and the status quo—except for the documentation! In addition to copious source-references in footnotes, there are more than 50 pages of statistics at the end of the book, and they are respectable statistics. . . . Whatever one may think of Mr. Seldes as a social philosopher, his references cannot be laughed away. . . . We keep asking ourselves, "Why doesn't someone sue him for criminal libel?" And then we turn again to those references, those footnotes, those 50-odd pages of records and we can't help wondering.[6]

Without going into the merits of the question under discussion, one must note that this contribution has won a hearing almost entirely on the basis of its documentation.

It is not necessary, however, to provide documentation in writing which does not purport to present research or which does not depend upon the formal presentation of evidence for its acceptance. Journalistic articles and articles in periodicals of general circulation as well as some textbooks are not documented. The scholar may write a popular treatment of his subject without documenting it, but when he writes for his fellow scholars he supplies the references. This distinction is as valid outside the classroom as in it. Only the uninformed regard documentation as a fetish of the college professor. Briefly, the purpose of documentation in research papers is two-fold: (1) to cite authority for initial assumptions or for statements made, and (2) to provide the reader with sources for further investigation of the background of the subject.

B. The Form of Documentation

Although the basic purposes of all documentation are the same, the means of attaining these ends have not been entirely standardized. There is, however, considerable agreement as to the form and use of reference citations in certain fields, such as the humanities, government publications, chemistry, and biology. In the publications of the social sciences and in reports in many fields, including engineering, footnotes are used for citing references, as is the practice in the humanities. Journals in the applied sciences vary in their practice: some use footnotes; others follow the documentary practice of gov-

[6] Charles W. Morris, a review of *One Thousand Americans* by George Seldes, *The Courier-Journal*, Louisville, March 14, 1948.

ernment publications or that preferred by many of the chemistry journals. (See the table below.) While most journals conform to the

Documenting Research Papers

Purpose	*Means of accomplishment*			
	Humanities publications	*Government papers*	*Many chemistry journals*	*Many biology journals*
Listing of sources	Bibliography at end of paper	Combination of footnotes and references at end of paper	References or literature cited at end of paper; items arranged alphabetically and numbered	Literature cited at end of paper
Citing of authorities or sources in text of paper	Footnotes	Superscript numerals referring to references at end of paper	Numerals in parentheses on level of the line which refer to items in literature cited	Name of author and date of article in parentheses
Giving additional information or explanation	Footnotes	Footnotes used sparingly	Footnotes used sparingly	Footnotes used sparingly

This table sums up what is said in this chapter concerning the common purposes of documentation and the variant means of accomplishing these purposes in different fields. The humanities system is widely used in the social sciences; in journal articles, footnotes are usually used for references, and no separate bibliography is given. Practice varies among journals in the applied sciences: some such journals use the government system of documentation, some the humanities system, and many the system favored by chemistry journals.

practices customary in their fields, the final editorial authority rests with the individual journal or press.

Some of the variations in the form of documentation in different fields are undoubtedly due to custom; many such variations, however, are functional differences which have come about because of special needs. Documentation in the humanities, with its extensive

footnotes and bibliographies, is well adapted to a field in which a long period of time and many variant readings and editions must be covered. The system of documentation widely used in government publications is serviceable and easily handled but is somewhat less flexible. The system favored by many chemistry journals combines a maximum of essential information with a minimum expenditure of space and time. The system of the biological journals gives a characteristic emphasis to the date by placing it in references immediately after the author's name, an emphasis which serves to recall that the date is often the key to the concepts underlying a paper.

Once a pattern of documentation has been chosen, it must be followed consistently. For example, though either a colon or a comma following the place of publication in a humanities bibliographical entry is correct, it is not permissible to vary the usage in documenting a single article.

IV. PRACTICES AND VARIATIONS IN DOCUMENTATION

Although complete familiarity with prevailing practices in documentation can come only through examination of papers and experience in preparing them, a description of the predominant variations is offered here as a guide to the student's observation and practice in documentation.

A. Humanities Publications

The system of documentation accepted in the humanities is well known through its use in scholarly books and articles and in theses in English, foreign languages, philosophy and the arts, and in history and the social sciences. This system is characterized by the use of footnotes for both citations of sources and explanatory notes, by the extensive use of bibliographies, by such abbreviations as *ibid.* and *op. cit.*, and by adherence to traditional practices in punctuation and capitalization. The items in long bibliographies, especially those in theses or books, may be classified as primary or secondary sources, or as books, periodicals, newspapers, etc.

The following examples of entries for a *bibliography* are typical of those used in the humanities.

Andrews, Edmund, *A History of Scientific English.* New York, Richard R. Smith, 1947. 342 pp.

Annual Report of the Board of Regents of the Smithsonian Institution, 1951. Washington, D. C., United States Government Printing Office, 1952. 580 pp.

KLAPPER, JOSEPH T. and CHARLES Y. GLOCK, "Trial by Newspaper," *Scientific American,* 180:16-21, February 1949.

New York Times, March 25, 1949.

SPRY, WILLIAM, "Homestead and Exemption Laws," *Encyclopaedia Britannica,* 14th edition, XI, 704-05.

These are examples of footnotes:

1 Edmund Andrews, *A History of Scientific English,* New York, Richard R. Smith, 1947, p. 116.

2 *Ibid.,* p. 107.

3 Joseph T. Klapper and Charles Y. Glock, "Trial by Newspaper," *Scientific American,* 180:17, February 1949.

4 Andrews, *op. cit.,* p. 106.

5 *Loc. cit.*

6 Editorial in the *New York Times,* March 25, 1949.

These are points to note:

1. Hanging indentation is used for the bibliography, paragraph indentation for footnotes.

2. In a bibliographical entry for a book or article by a group of authors, the name of the first author is inverted and the others are in normal order. The bibliography is arranged in alphabetical order according to the authors' last names; if there is no author, the item is alphabetized according to the first word of the entry, except for *a, an,* or *the.* In footnotes the names of authors appear in normal order.

3. Titles of articles in footnotes and bibliographies are placed in quotation marks; titles of books, journals, and newspapers are italicized. (In manuscript, italics are shown by underlining.)

4. In footnotes the abbreviation *ibid.* (*ibidem*—in the same place) is used to refer to another page of the immediately preceding reference. After other references have intervened, the abbreviation *op. cit.* (*opere citato*—in the work cited) is used to refer again to an author and work already cited. The abbreviation *loc. cit.* (*loco citato* —in the place cited) is used for a second consecutive reference to the same author, same work, and same page.

Although the humanities system of documentation is not common in the sciences, a number of scientific publications use variations

of it. Among these publications are some physics journals which cite references entirely through footnotes as the following examples illustrate:

[1] E. E. Motta and G. E. Boyd, Phys. Rev. **73,** 1470 (1948).
[2] D. N. Kundu and M. L. Pool, Phys. Rev. **74,** 1775 (1948).
[3] Medicus, Preiswerk, and Scherrer, Helv. Phys. Acta. **23,** 299 (1950).
[4] E. Fermi, *Nuclear Physics* (University of Chicago Press, Chicago, 1950), p. 7.
[5] L. G. Mann and P. Axel, Phys. Rev. **80,** 759 (1950).
[6] Rose, Goertzel, and Perry, Oak Ridge National Laboratory Report **1023** (unpublished).
[7] M. Goldhaber and A. W. Sunyar, Phys. Rev. **83,** 906 (1951).

(From Harry T. Easterday and Heinrich A. Medicus, "Isomeric Transitions in Tc^{93} and Tc^{96}," *Physical Review,* 89(4):752-753, February 15, 1953.)

B. Government Publications

In a system of documentation much used in government publications and in journals of the applied sciences, all citations of sources are combined in "References" at the end of the article and cited in the text by superscript numerals (numerals placed above the line of type). The references appear in the order in which they are cited, not alphabetically; in this respect they resemble footnotes although they serve as a bibliography as well. In this system, as in most scientific documentation, footnotes are given at the bottom of the page only as explanatory notes, not for citation of sources. If the same reference is cited more than once in the text of a paper, the numeral first used is repeated for all citations of this reference, and the reference is listed only once at the end of the paper. Thus the citations refer to articles as a whole, not to specific pages. In this system capitalization and punctuation are reduced to a minimum; in titles of articles only the first word and proper nouns and adjectives are capitalized. Italics and quotation marks are not used for titles. The points will be observed in the following example:

References

(1) Altenderfer, Marion E.: Relationship between per capita income and mortality, in the cities of 100,000 or more population. Pub. Health Rep. **62:**1681-1691 (1947).

(2) Department of Commerce, Bureau of the Census: Sixteenth Census of the United States: 1940, Population, Vol. II. U. S. Government Printing Office, Washington, 1943.
(3) Survey of buying power, 1940. Sales Management **48**:84-283 (1941).
(4) Department of Commerce, Bureau of the Census: Sixteenth Census of the United States: 1940, Population, Vol. I. U. S. Government Printing Office, Washington, 1942.
(5) Department of Commerce, Bureau of the Census: Vital Statistics of the United States: 1940, Part II. U. S. Government Printing Office, Washington, 1943.
(6) Department of Commerce, Bureau of the Census: Vital Statistics of the United States, Supplement 1939-1940, Part III. U. S. Government Printing Office, Washington, 1943.

(From Marion E. Altenderfer and Beatrice Crowther, "Relationship between Infant Mortality and Socioeconomic Factors in Urban Areas," *Public Health Reports,* 64:331-337, March 18, 1949.)

C. Scientific and Industrial Publications

The system of documentation favored by many chemistry, scientific, and industrial journals uses numerals in the text of the paper to refer to a list of references at the end. However, in journals using this system, references are arranged in alphabetical order by the last name of the author; the items in this list are then numbered consecutively. These numerals are inserted in parentheses in the text of the paper to cite the references which they identify. Obviously the numerals in the text will not be in consecutive order, since the number of each article referred to is determined by the author's place in the alphabetical list. When several authorities are cited for a single statement, the designative numerals are in the same parentheses, for example (7, 3, 2, 5). Exact page references are seldom given in these parenthetical citations since the sources listed at the end of the article are usually short.

Though details of documentation differ among chemistry journals, in general certain practices are characteristic. In the list of references, journals are designated by the abbreviations given them in the *Decennial Index of Chemical Abstracts* and their titles are italicized. Titles of articles are usually not included, but when given they are placed in quotation marks, as are the titles of books. Reference to

journal articles is by volume (in boldface type) and page, with a comma between the two; the year follows in parentheses.

The following examples illustrate these points:

(1) Grosse, A. V., Hindin, S. G. and Kirshenbaum, A. D., *J. Am. Chem. Soc.*, **68**, 2119 (1946).
(2) Grosse, A. V., Kirshenbaum, A. D. and Hindin, S. G., *Science*, **105**, 101 (1947).
(3) Hevesy, G. V., and Paneth, F., "Lehrbuch der Radioaktivität," 2nd ed., Chap. 17, pp. 164-73, Leipzig, Germany, 1931.
(7) *Rev. Sci. Instruments*, **19**, 124 (1948).

(From *Analytical Chemistry*, 21:390, March 1949. Copyright, American Chemical Society.)

(1) Barron, H., *British Plastics*, **11**, 467 (1940).
(2) Bennett, H., ed., "Emulsion Technology," Brooklyn, Chemical Publishing Co., 1946.
(6) Cupples, H. L., U. S. Dept. Agriculture, Bureau of Entomology and Plant Quarantine, **E-607** (1943).

(From *Industrial and Engineering Chemistry*, 41:796, April 1949. Reprinted by permission.)

D. Biology Journals

Among biology journals the prevailing style of documentation is the one described in the style brief of the Wistar Institute Press. Sources are listed in the Literature Cited or References at the end of the article. The items are arranged alphabetically by the last names of the authors, with the year of publication next, followed by the article title, and other publication data. If an article has more than one author, the name of only the first author is inverted, the others appearing in normal order. Only the first word of article titles is capitalized, and titles are not put in quotation marks. Titles of journals are abbreviated in accordance with standard abbreviations given in the *Wistar Institute Style Brief*, the catalogue of the Army Medical (Surgeon-General's) Library, Washington, D. C., the *Quarterly Cumulative Index Medicus*, and the *World List of Scientific Periodicals.*

LITERATURE CITED

ADLER, A. 1939 Melanin pigment in the central nervous system of vertebrates. J. Comp. Neur., *70:* 315-329.

BARDEN, R. B. 1942 The origin and development of the chromatophores of the amphibian eye. J. Exp. Zool., *90:* 479-519.

BISHOP, S. C. 1943 Handbook of salamanders. Comstock Publishing Company, Ithaca.

DETWILER, S. R. 1917 On the use of Nile Blue Sulphate in embryonic tissue transplantation. J. Exp. Zool., *13:* 493-497.

——— 1937 Observations upon the migration of neural crest cells, and upon the development of the spinal ganglia and vertebral arches in Amblystoma. Am. J. Anat., *61:* 63-94.

DETWILER, S. R., AND K. KEHOE 1939 Further observations on the origin of the sheath cells of Schwann. J. Exp. Zool., *81:* 415-435.

DUSHANE, G. P. 1938 Neural fold derivatives in the Amphibia. Pigment cells, spinal ganglia and Rohon-Beard cells. J. Exp. Zool., *78:* 485-503.

——— 1943 The embryology of vertebrate pigment cells. Part I. Amphibia. Quart. Rev. Biol., *18:* 109-127.

FARIS, H. S. 1924 A study of pigment in embryos of Amblystoma. Anat. Rec., *27:* 63-76.

(From Jean Piatt, "Transplantation Experiments between Pigmentless and Pigmented Eggs of Amblystoma punctatum," *Journal of Experimental Zoology,* 118: 126, October 1951.)

In citing sources in the text of the paper, the last name of the author and the date of the article are given in parentheses when the work is first referred to, for example, (Brown, '47). If the author's name has already been mentioned in the text, only the date is in parentheses, for example, according to Brown ('47). When additional articles by the same author in the same year are cited, they are distinguished by small letters, a, b, etc., for example, '47a, '47b. Though page references are seldom necessary in textual citations, they may be given either following the date (Brown, '47, p. 119) or in separate parentheses, as in one of the examples given later. References in the text and the Literature Cited should correspond; no article is referred to in the text which is not listed at the close of the paper, and no article is listed which has not been referred to.

The following examples of textual citations illustrate the practices which have been described.

. . . Weed ('32, p. 625, and earlier papers) presents evidence . . .
. . . described by Cushing and Weed ('15) . . .

. . . by Globus ('37). . . . He includes (p. 243) . . .
. . . by Globus ('37, fig. 95A) is similar . . .

(From William M. Shanklin, "The Development and Histology of Pituitary Concretions in Man," *Anatomical Record,* 94: 598, 606, April 1946.)

The following examples of footnotes show how such notes, though not used for citing sources in scientific documentation, are used for necessary explanation.

[1] This investigation has been aided by grants from the Rockefeller Foundation, the Carnegie Corporation and the Carnegie Institution of Washington, in the last named of which the author has enjoyed the status of Research Associate.

[16] The terms ventricular and non-ventricular have been chosen rather than ependymal and non-ependymal since it leaves open the question of what becomes of the cells located next to the ventricular cavity which His termed "Keimzellen" and which may give rise to neuroblasts as well as ependyma.

(From Ross G. Harrison, "Wound Healing and Reconstitution of the Central Nervous System of the Amphibian Embryo after Removal of Parts of the Neural Plate," *Journal of Experimental Zoology,* 106:27, 67, October 1947.)

Since form in scientific articles is almost entirely functional, it is subject to change as new needs arise. For this reason the writer should never become so fixed in the use of one form that he is unable to adapt himself to another. The advantages of some degree of standardization in documentation are obvious, and the further standardization of literature citations is among the editorial problems given consideration at recent scientific meetings.[7] However, since some of the differences in the form of documentation in different fields have remained because the documentary needs of those fields differ, complete standardization is unlikely.

In conclusion, it must be emphasized that this review of documentary practice is by no means intended as a substitute for the study of the journals and their style sheets. Rather it is intended to give the student an idea of what to look for and to sharpen his observation. A trained eye is instantly aware of punctuation and capitals, of

[7] *Science,* 119:529, April 23, 1954.

sequence, of whether hanging or paragraph indentation is used. When the student attains this proficiency, format need no longer be confusing to him and can be kept in its rightful place as secondary to content.

STUDY SUGGESTIONS

1. According to Soule's *Library Guide for the Chemist* (pp. 40-41), "All references should invariably answer three questions: Who did the work? When was it published? Where can it be found?" Show how the different systems of documentation fulfill this requirement.
2. Examine the documentation in a representative group of scientific periodicals. How much variation do you find among periodicals in the same field? In different fields? Are the variations in details of punctuation and capitalization or in content and arrangement?
3. Explain why no one type of documentation is suitable for all purposes. In your opinion would it be possible to reduce the variations among different forms of documentation without impairing their usefulness?
4. Conway Zirkle in *Science*, 120:189-90, July 30, 1954, points out several instances in which fraudulent data have been cited successively in different articles. How do such accumulations of eιror come about? How can they be avoided?
5. When should documentary sources be included verbatim in an appendix and when is it sufficient to cite them in footnotes or other references?
6. Arrange the following items as a correct bibliography or list of references for each of the four principal types of documentation described in this chapter, assuming that the order given here represents the order in which the sources were referred to in the paper to be documented.

   Author—Willard C. Brinton; Title—Graphic Methods for Presenting Facts; Place of publication—New York, The Engineering Magazine Company; Date of publication—1919.

   Author—None indicated; Title—Telling lines—some notes on graphs; Place of publication—*Scope*, Volume 3, No. 11, pages 7-11; Date of publication—Spring 1953.

   Author—C. C. Wylie; Title—Astronomy, Maps and Weather; Place of publication—New York, Harper & Brothers; Date of publication—1942.

   Author—Ruth C. Christman; Title—Illustrations for scientific publications; Place of publication—*Science*, Volume 119, pages 534-538; Date of publication—April 23, 1954.

Author—David Diringer; Title—The Hand-Produced Book; Place of publication—New York, Philosophical Library; Date of publication —1953.

Author—Don Livingston; Title—Film and the Director; Place of publication—New York, The Macmillan Company; Date of publication—1953.

CHAPTER 15 GRAPHIC AND PICTORIAL ILLUSTRATION

And ye who wish to represent by words the form of man and all the aspects of his membrification, get away from that idea. For the more minutely you describe, the more you will confuse the mind of the reader and the more you will prevent him from a knowledge of the thing described. And so it is necessary to draw and describe. LEONARDO DA VINCI, Notebooks, translation by J. PLAYFAIR MCMURRICH.

I. NONVERBAL ILLUSTRATION

From the time of the earliest drawings which recorded the knowledge of primitive peoples, illustration has shared with words the task of factual communication. Illustration, to readers generally, implies embellishment or adornment. While the aesthetic value and pictorial interest of scientific illustrations are at times notable, their established place in scientific writing is due to the clarity they contribute, the recorded evidence of observations which they sometimes afford, and the conciseness and efficiency with which they may express complicated data.

It is axiomatic that an illustration may contribute more to clarity than hundreds of words of description or explanation. Photographs—taken directly or with the aid of the microscope or telescope—may offer evidence of the geological fault, of abnormal cell structure, of

the effects of erosion, and of the eclipse. Through the use of tables and graphs the scientific writer can bring out a meaning which would otherwise be lost in a maze of figures.

The growing use of visual means of expression is due in part to modern technical developments. The present-day writer has at his command techniques far beyond those of the comparatively simple wood cuts and drawings to which the very early writer was largely limited. The relatively new field of photography has expanded to include at one extreme the electron micrograph with a magnification of more than 100,000 times and at the other the photographs of stars millions of light years away. The slow-motion picture, the X-ray, and the devices for photographing interior surfaces of the body have all extended the range of man's visual observations.

Graphic devices—linear, geometrical, and symbolic—for expressing data have similarly undergone a long and recently rapid development. While some of these graphic devices are intelligible only to the person with advanced mathematical training, others are used in writing intended for the general reader.

II. TYPES OF ILLUSTRATIONS

Among the types of scientific illustrations the scientific writer may choose those best suited to his needs: "Photographs and drawings are especially important in the descriptive phases of science. Diagrams of apparatus and graphs of data are mainly required in the experimental and quantitative phases." [1] The illustrations discussed in the present sections have been classified somewhat informally according to function and usage rather than according to methods of reproduction, which are discussed in Section III of this chapter.

A. Drawings

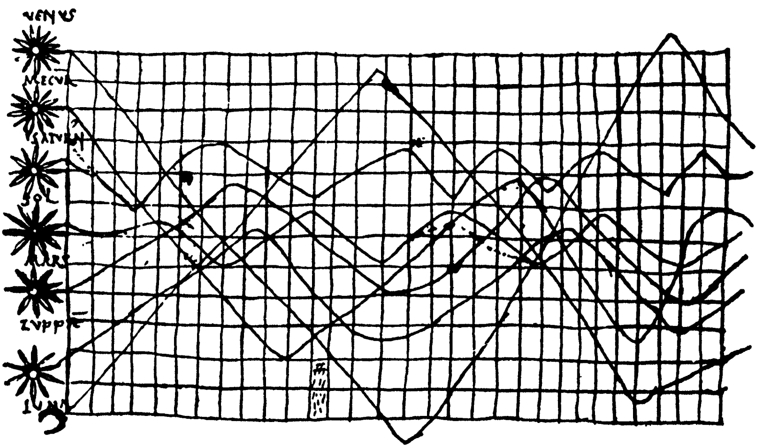
Of the many types of illustrations—both graphic and pictorial—*drawings* are incomparably the oldest. Picture writing, from which the pictograph, or picture writing, as used in modern advertising is descended, is in fact the most primitive form of writing.

> The ideas of writing and drawing were identical in prehistoric Egypt and in early Greece, as it is shown by the Egyptian word *s-sh* and by

[1] Sam F. Trelease, *The Scientific Paper*, 2nd ed., Baltimore, The Williams and Wilkins Company, 1951, p. 112.

the Greek *graphein,* which mean both "writing" and "drawing." The word *graphein* gave us the main component of many words connected with writing, such as pictography, calligraphy, stenography, iconography, and so forth.[2]

Though drawing as a method is used in preparing many types of illustrations, it is convenient when thinking in terms of function and purpose to restrict the term *drawings* to those figures done with pencil,



Carl B. Boyer, "The Invention of Analytic Geometry," *Scientific American* 180(1):45, January 1949.

This tenth-century graph charts by co-ordinates the paths of the sun, moon, and known planets, shown by symbols at the left.

pen, crayon, or brush which represent fairly closely the outward appearance of the object or structure depicted. Because of their many advantages drawings remain today one of the most useful types of scientific illustrations.

The art of drawing is supremely adaptable. Crude sketches are often resorted to even in conversation when words are inadequate to explain or describe fully the subject of discussion. Yet the line drawing so much used in the biological sciences is capable of conveying delicate detail which is lost in the photograph, and it often has high analytical as well as pictorial value. The drawing may be done from direct observation with or without the use of the microscope, or, when necessary, from documentary evidence or museum recon-

2 David Diringer, *The Alphabet,* New York, Philosophical Library, 1948, p. 25.

structions. Finally, drawings may be entirely freehand or may be done according to rigid specifications with the aid of measurements and instruments, as in mechanical drawing. Successful scientific illustrating involves not only drawing skill but the ability to handle instruments and materials, to letter, and to represent shape and size accurately.

The professional artist in the sciences may have standards of objectivity and exactitude comparable to those of the scientist himself. The late Max Brödel, Professor of Art as Applied to Medicine in The Johns Hopkins University, exemplified the scientific attitude at its best.

> The essential point, aside from his technical skill as an artist, was his refusal to accept anybody else's words, drawings or impressions, unpublished or published, as authoritative. He insisted, instead, on seeing for himself the structures to be portrayed. He believed, and on numerous occasions propounded the thesis with vigor, that the advance of knowledge in many fields has been seriously retarded by copying from others. One of his favorite expressions was "the perpetuation of errors." [3]

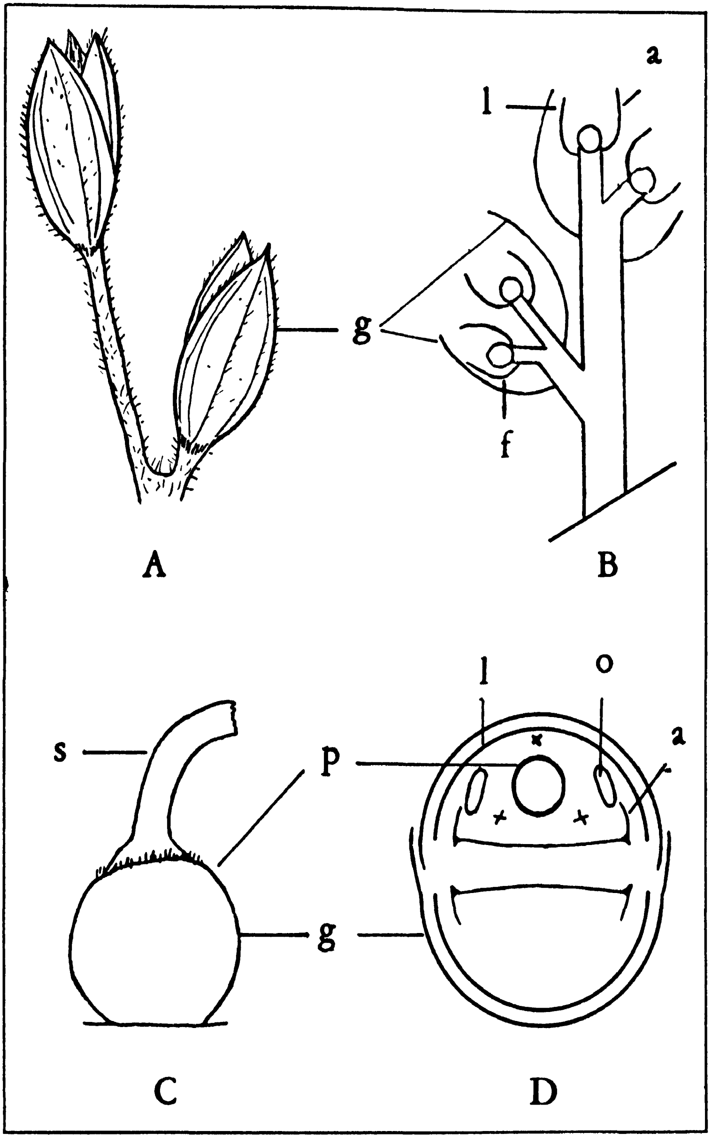
The visual appeal as well as the instructional and informative value of drawings leads to their widespread use in a great variety of publications.

B. Diagrams, Maps, and Charts

Technically, diagrams are drawings; nevertheless there is a valid functional distinction between the two. The *diagram* is relatively a more abstract representation of reality, and considerable freedom is exercised in selecting and arranging its parts to suit the purpose of the writer. Features not central to the immediate purpose are ignored, and devices to show time, space, and other relationships are freely used. Schematic representation, schematic drawing, and symbolic representation are other terms sometimes used to denote abstract as opposed to realistic representations.

Maps are likewise conventionalized representations of reality, but their function is to represent areas of land, sea, or sky. Numerous types of maps are used in factual and technical writing, among them

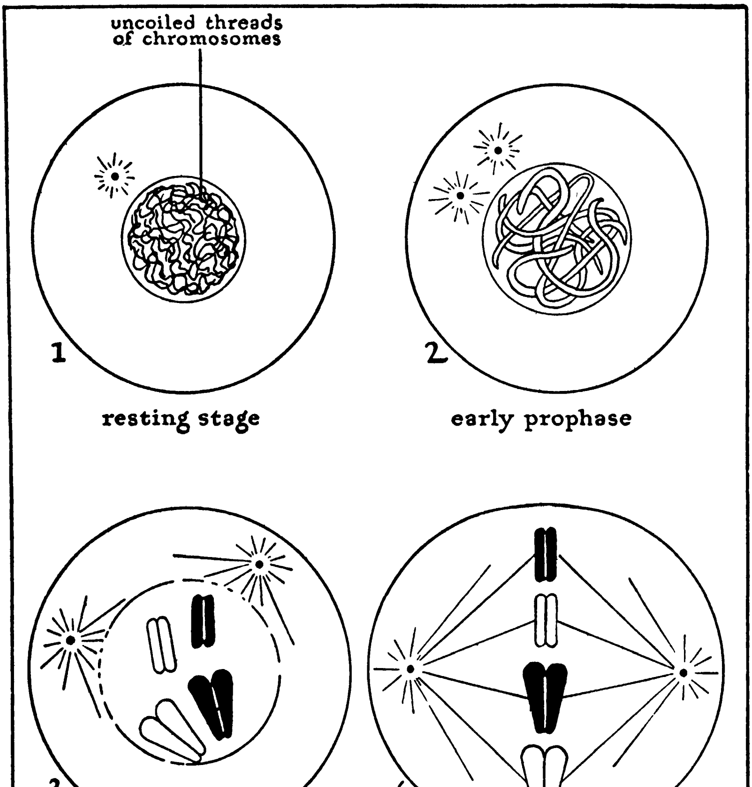
[3] *Three Unpublished Drawings of the Anatomy of the Human Ear*, Philadelphia, W. B. Saunders Company, 1946.



O. T. Bonnett, "The Inflorescences of Maize," *Science*, 120 78, July 16, 1954.

The diagrammatic sketches at the right show the structural details of the plant drawings on the left.

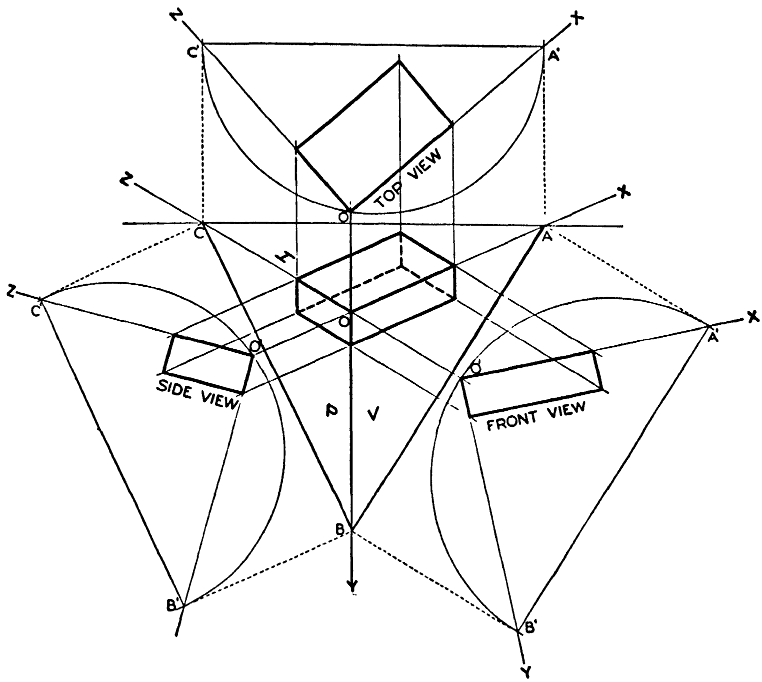
contour, profile, historical, linguistic, political, route, and weather maps. The informative value and pictorial appeal of maps may be enhanced by the use of color or shading, by the addition of pictures,



E. T. Smith, *Exploring Biology*, 4th ed., Harcourt, Brace and Company, 1953.

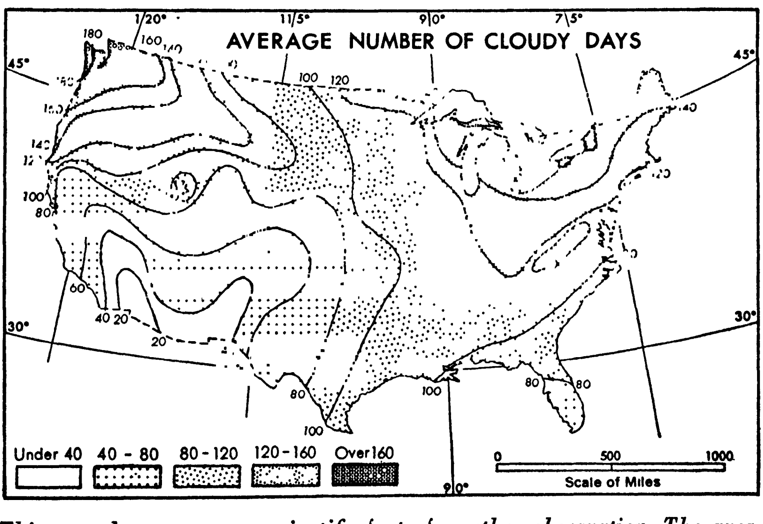
A complex process can be demonstrated by diagrammatic drawings. This series illustrates the stages of mitosis in the fertilized egg.

lines, or figures, or by superimposing one map on another to show area relationships. A map should have a title indicating its subject and the area covered. A key or legend should give explanations of symbols or lines to enable the reader to interpret the map. The scale to which the map is drawn should accompany it.



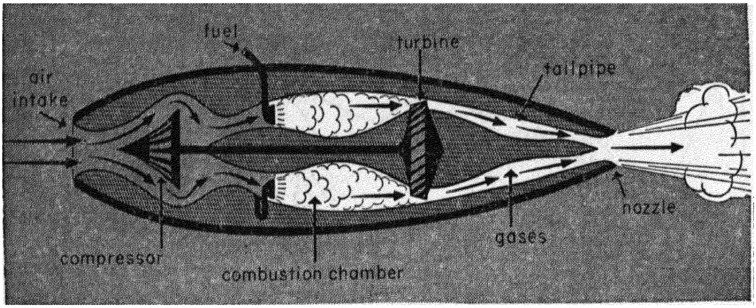
F. E. Giesecke, A Mitchell, and H. C. Spencer, *Technical Drawing*, The Macmillan Company, 1949, by permission of the publisher.

By means of a diagrammatic drawing, three sides of a rectangular cube and their relationships can be represented on a two-dimensional plane.



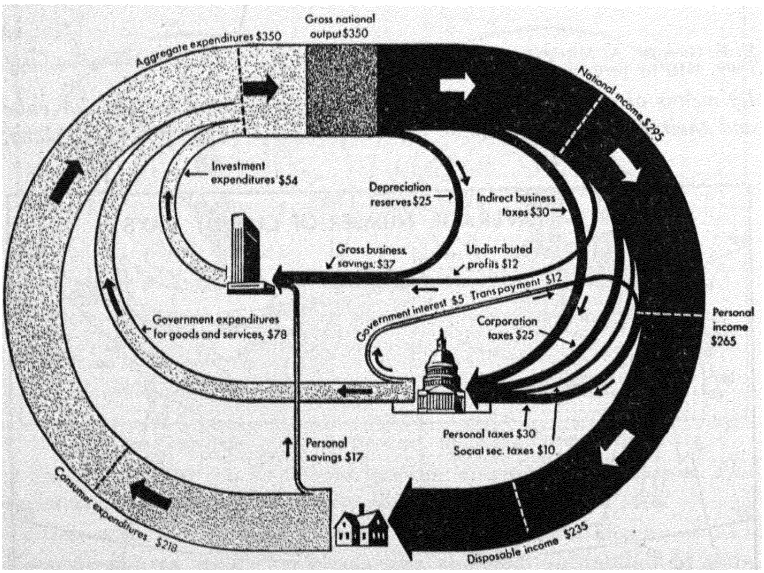
This map demonstrates a scientific fact of weather observation. The average number of cloudy days per year is indicated by the different shading.

The term *chart* is sometimes used interchangeably with *map* or *graph*. However, the word *chart* may be reserved for presentations designed to show procedure or process, such as flow charts, or to show organization.



Ruchlis and Lemon, *Exploring Physics*, Harcourt, Brace and Company, 1952.

This example of a flow chart shows a sectional view of a jet engine. The reaction of hot expanding gases rushing out the nozzle kicks the engine forward.



A. E. Burns, A. C. Neal, and D. S. Watson, *Modern Economics*, 2nd ed., Harcourt, Brace and Company, 1953.

A flow chart often shows a complete cycle—in this instance, the circular flow of national output and income in billions of dollars. The complexity of the material charted here reveals the possibilities of this type of illustration.

C. Tables

A *table* is a means of arranging data in columns, usually three or more, so that it may be easily read and comprehended. Tables may be used to present either *observed* data which record the immediate results of experiment or observation, or *derived* data obtained from the original data by calculation. Tables in which the data are arranged to bring out certain trends or correlations are sometimes called special-purpose tables. In tables of this type the figures may be rounded off, but observed data should be recorded exactly.[4]

Each table should have a *number* and a *title* which answers the questions *what, where, when,* for example, Coal Production in West Virginia, 1940-50. The title should be clear, concise, and direct. The second of the following titles [5] is better than the first.

Table 8.—*Total amount of lumber in board feet consumed in all mines in the United States in the 5-year period 1940 to 1944, inclusive*

Table 8.—Lumber used by mines in the United States, 1940-44

The *stub* in a table is the first column at the left, which identifies the horizontal lines of figures. The *boxhead,* at the top of the table above the columns, provides space for the *column headings.* Sometimes a second tier of boxes is used to present a subclassification. The *unit of measurement* and the *source* of the data should be given. The classification, which of course varies with the purpose of the table, may be chronological, geographical, or categorical.

The arrangement of the table should be as clear and uncluttered as possible. Footnotes should be used for necessary explanation to avoid complicating the title or mixing words and figures in the table itself. It may be desirable to use symbols such as asterisks and daggers to indicate footnotes since numerals used for this purpose may be confused with tabular data. Double lines or heavier lines may be used to indicate divisions within the table. Totals may be placed at the bottom and right or at the top and left. Proper organization of tabular material to present information in the clearest manner

[4] Herbert Arkin and Raymond R. Colton, *Graphs: How to Make and Use Them,* New York, Harper & Brothers, 1940, p. 224.

[5] E. vH. Larson, *Tables for Technical Writers,* United States Department of Agriculture Forest Service, Northeastern Forest Experiment Station, Station Paper No. 3, May 1947.

possible is not an easy task. Visual and logical organization must be undertaken by the author and not left to the ordinary printer. An experienced publisher, on the other hand, is usually able to carry the author's intentions one step further through his experience with visual techniques.

APPENDIX VI [6]

Estimated Research and Development Expenditures in the United States, 1941-52

[*In millions of dollars*]

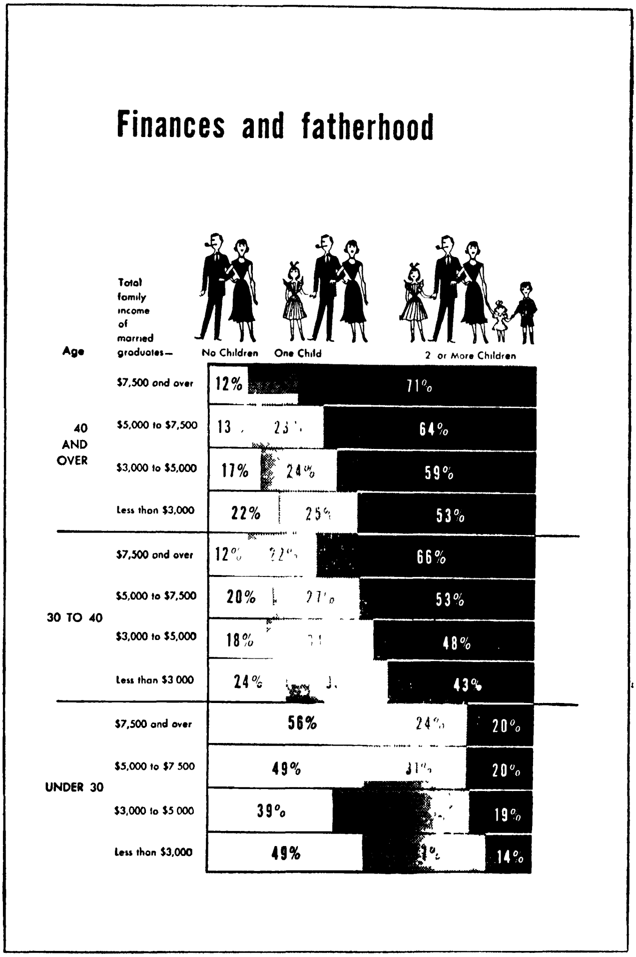
Year	*Total*	*Source of funds*		*Use of fund by type of institution*		
		Other	*Federal*	*Industrial*	*University*	*Federal*
1941	800	560	240	520	80	200
1942	930	590	340	600	90	240
1943	1,050	420	630	650	100	300
1944	1,200	430	770	700	110	390
1945	1,300	420	880	750	120	430
1946	1,490	830	660	890	130	470
1947	1,810	1,020	790	1,120	170	520
1948	2,060	1,140	920	1,290	200	570
1949	2,080	1,030	1,050	1,310	220	550
1950	2,240	1,200	1,040	1,430	240	570
1951	2,590	1,280	1,310	1,630	260	700
1952	2,930	1,290	1,640	1,820	280	830

Source: Research and Development Board, Department of Defense.

D. Graphs

The term *graph* is sometimes extended to include a variety of symbolic representations, but the usage followed here is the stricter one of applying the term *graph* only to visual presentations of numerical data. Since graphs are not intended to show details, they are often accompanied by tables presenting numerical data on which the graphs are based. According to Worthing and Geffner:

[6] *The First Annual Report of the National Science Foundation, 1950-51,* Washington, D. C., United States Government Printing Office.



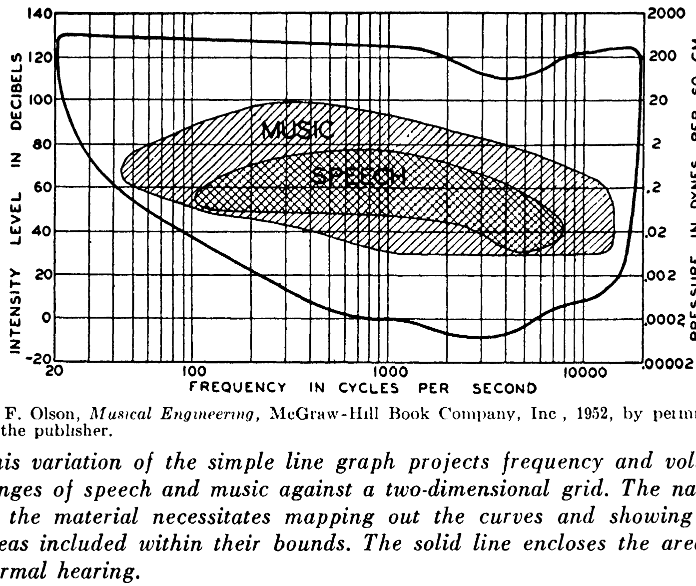
E. Havemann and P. S. West, *They Went to College,* Harcourt, Brace and Company, 1952.

A bar graph shows relationships. Here, three elements represented by degrees of shading are compared. This type of graphic presentation will be readily understood by the general reader.

The graphical method of presenting data is an adaptation of the principles of Descartes' analytic geometry, whereby numerical values are represented in geometrical form by the length of a line, the area of a surface, the volume of a solid, or the rotation described by an angle. The fact that all measurable quantities may be given such representation does not mean that all data should be plotted. For certain data a graph means little more than wasted time and labor. For other

data, failure to graph results not only in a loss of time and energy, but also in a failure to perceive significant relations. A decision as to whether or not to plot must be trusted to one's common sense.[7]

Graphs are used in scientific work for two purposes: (1) as a means of presenting data and indicating trends, and (2) as a tool in making computations.[8] While the same graph may serve both purposes, one purpose usually predominates.



H. F. Olson, *Musical Engineering*, McGraw-Hill Book Company, Inc., 1952, by permission of the publisher.

This variation of the simple line graph projects frequency and volume ranges of speech and music against a two-dimensional grid. The nature of the material necessitates mapping out the curves and showing the areas included within their bounds. The solid line encloses the area of normal hearing.

Among the types of graphs in general use for the presentation of data are the *bar graph*, the *line graph*, the *pie graph*, and the *picture graph* with their numerous adaptations and variations.

The *bar graph* is extensively used to show relative quantities or amounts with no implication of causal relationship.

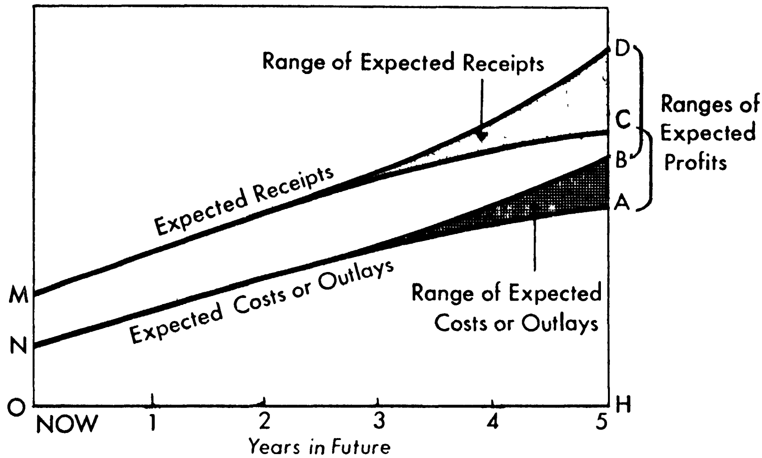
The *line graph* is to be preferred when the purpose is to show comparative trends or values over a long period of time. In a line graph a vertical axis (the ordinate) and a horizontal axis (the abscissa) are used to represent the two variables to be plotted. When

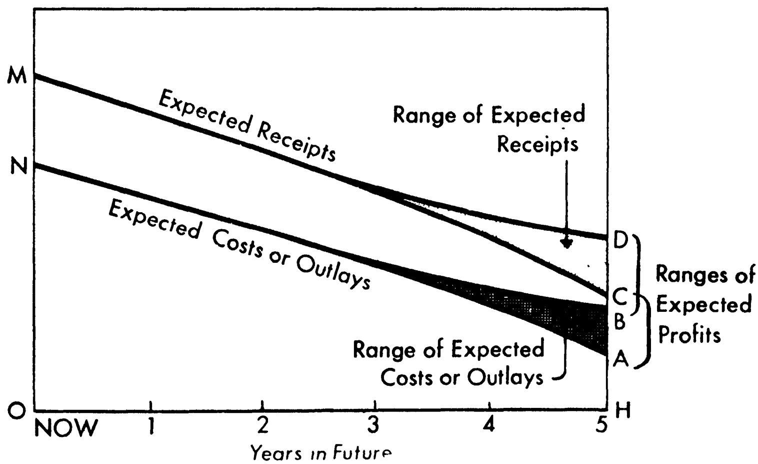
[7] Archie G. Worthing and Joseph Geffner, *Treatment of Experimental Data*, New York, John Wiley & Sons, Inc., 1943, p. 29. Reprinted with permission.

[8] For extended discussions of the types of graphs used for computations see *Ibid.*, pp. 36-55, and Arkin and Colton, *op. cit.*, pp. 173-96.

one of the variables is time, it should be represented by the horizontal axis. The background on which the lines are drawn is known as the *grid.*

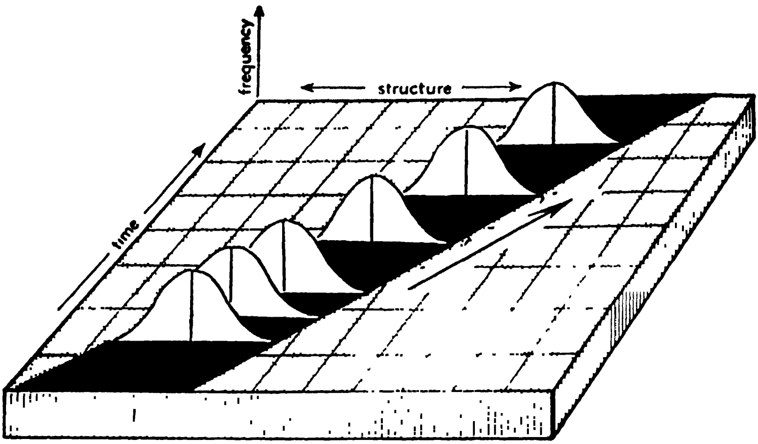
The *pie* or *circle graph* is an excellent device to represent partition or classification. One merit of the well-done *picture graph* is its eye





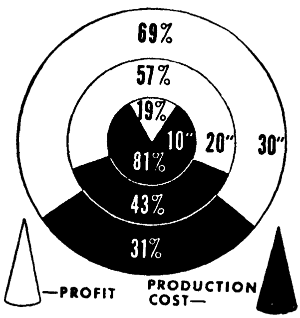
A E Burns, A. C Neal and D. S. Watson, *Modern Economics*, 2nd ed., Harcourt, Brace and Company, 1953.

These two line graphs show long-term business expectations for two different firms over a period of five years—the top a rise in receipts, the bottom a decline in receipts. The letters in the graph indicate only relative numerical values. Note that the time variables are represented on the horizontal axes.



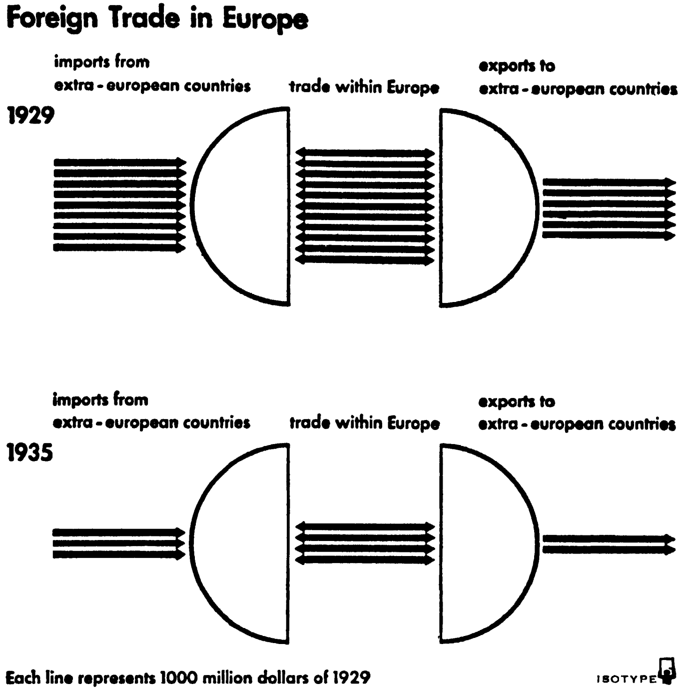
R. C. Moore, C. G. Lalicker, A. G. Fischer, *Invertebrate Fossils,* McGraw-Hill Book Company, Inc., 1952, by permission of the publisher.

This is a three-dimensional line graph—time, frequency, and structure—that makes a statistical comparison of an evolving strain in successive populations. Populations are represented by the frequency curves, which show the structural overlappings and variations.



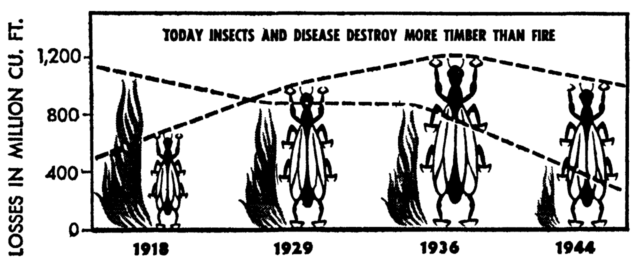
Forestry and Paper, 2nd ed., P H. Glatfelter Company, Spring Grove, Pennsylvania.

This pie, or circle, graph is composed of three individual pie graphs each of which represents a tree diameter in inches. As the graph reveals, a higher percentage of profit is realized as the size of the tree increases.



O. Neurath, *Modern Man in the Making*, Alfred A. Knopf, 1939, by permission of the publisher.

Abstract symbols, rather than representational pictures, can be effectively used in a picture graph.



"The Nation's Wood Supply," American Forest Products Industries, Inc., 1319 Eighteenth Street, Northwest, Washington 6, D C.

The picture graph is a dramatic means of statistical representation and facilitates comprehension.

appeal. It is, therefore, much used in journalistic, social science, and business writing. Where a direct visual connection can be set up between the measure and the thing measured, speed of comprehension and memory are often greatly aided. When the help of specialists in visual presentation is available, it can often greatly enhance the comprehension of material that is otherwise difficult to present. For example, several medical house organs have in recent years taken advantage of newer visual techniques in the presentation of difficult material.

Graphs, like other illustrations, may be misleading if not offered in good faith and in accordance with accepted procedure.[9] The writer should guard against practices which lead to errors in interpretation. A partial listing of such possible sources of error follows:

1. *Omission* of *essential facts.* Each graph should have a title stating the subject, time, and place covered. Whether graphs are used in place of or as a supplement to tables showing the same data depends on the nature of the material, the purpose of the presentation, and editorial preference. In either case such pertinent facts as dates and sources of information should be included.

2. *Omission of the zero base line.* In a line graph showing comparison it may be desirable or even necessary to omit the zero base line in order to avoid an excess of waste space at the bottom of the graph. If such an omission must be made, the numerical point at which the base of the graph begins should be made perfectly clear.

3. *Misleading proportions.* In line graphs a reasonable proportion should be maintained between horizontal and vertical dimensions. An extreme extension in either direction may give a false picture. For example, if the points on the horizontal axis representing time are spaced far apart in relation to the points on the vertical axis representing the second value, the fluctuation will appear to be reduced. If the points on the vertical axis are far apart, the fluctuation will appear to be increased.

4. It may be necessary to indicate amounts on the vertical axis of a line graph in thousands or millions. This value should be indicated clearly in the *scale caption* which is printed at the top or side

[9] The manual of the American Standards Association, *Engineering and Scientific Graphs for Publication,* Z 15.3-1943, is a valuable reference in this connection and may be obtained at small cost from the Association, 70 East Forty-fifth Street, New York 17, N. Y.

to indicate what the values represent, for example, thousands of tons of coal, millions of kilowatt hours.

E. Photographs

The ordinary photographic print has long been useful in scientific writing. Later technical developments such as the motion picture, the X-ray photograph, the color photograph, and the aerial photograph, as well as the photograph taken through the telescope, the photomicrograph, and the electron micrograph, have amply proved their value in scientific and technical fields. Even the long-known principle of the stereoscope has recently been utilized in scientific illustrations to produce three-dimensional effects. Indeed, so consequential is photography in science that some knowledge of photographic technique is virtually a prerequisite for work in many scientific fields.[10]

III. HANDLING OF ILLUSTRATIONS

Accuracy and objectivity are as imperative in handling illustrations as in any other phase of scientific writing. When relied on as sources of information they must be examined critically. When the writer prepares such graphic and pictorial materials for his paper, he must be schooled in the principles and techniques involved.

A. Treatment as Evidence

Illustrations may be misleading if precautions are not observed in offering and interpreting them. The apparent resemblance between a close-range photograph of a drop of milk falling into a saucer and a photograph of an atomic explosion taken at a distance shows, for example, that one cannot always believe one's own eyes. Photographs and other illustrations have on occasion been faked or forged, and visual media are well known to the propagandist.

Graphs, tables, and charts can be no more accurate than the data which they depict. An imposing and elaborate illustration offers in itself no assurance that the information upon which it is based is up-to-date, authoritative, and unbiased. The writer is obligated to supply the reader with details, when applicable, as to the sources

[10] Numerous useful suggestions concerning photography in connection with scientific writing are given in Trelease, *op. cit.*, pp. 123-43.

of the statistics or measurements on which graphs, drawings, or models are based, the conditions under which photographs were taken, and the extent of reduction, enlargement, or magnification, if any.

B. Preparation for Publication

The importance of illustrations in scientific writing is affirmed by the careful directions which editors usually give for their preparation. The scientific writer, therefore, should keep editorial requirements in mind when planning and preparing illustrations. No final drawing or labeling should be undertaken without first consulting the publisher.

> Clearness and cost are the controlling factors for consideration in preparing illustrations for publication. Before preparing original drawings or photographs, the method by which they are to be reproduced should be carefully determined. Unsatisfactory reproductions are frequently attributed to lack of ability on the part of the engraver, when the cause is due chiefly to copy.[11]

Whatever categories may be used to group illustrations according to function and purpose, as in Section II of this chapter, the originals from which illustrations are made are usually classified, from an editorial viewpoint, as drawings or photographic prints. Line drawings are the least expensive to reproduce. Wash drawings[12] and photographs must be reproduced by halftone engraving processes. The use of the more expensive color processes is limited by their greater cost, but when available, color processes have great analytical, as well as aesthetic, possibilities.

The following quotation from a style sheet issued by the editors of *Industrial and Engineering Chemistry* is a useful statement of points they consider important in preparing illustrations for publication.

> *Illustrations.* Submit original drawings (or sharp prints) of graphs and diagrams and clear glossy photographs. Prepare original drawings on tracing cloth or high quality paper; use black India ink and a lettering set. Choose graph papers with blue cross-sectional lines; other

[11] *The Wistar Institute Style Brief*, Philadelphia, The Wistar Institute Press, 1934, p. 44.

[12] A wash drawing is a line drawing with tones of gray added and hence must be reproduced by halftone processes.

> colors interfere with good reproduction. Label ordinates and abscissas of graphs along the axes and outside the graph proper. Figure captions and legends are set in type and need not be lettered on the drawing.
>
> Number all illustrations consecutively. Supply typed captions and legends (plus courtesy lines for photos) on a separate page.[13]

In the publishing processes, illustrations are handled separately from the text; for this reason they should always be on separate sheets of paper. Most illustrations are accompanied by explanatory captions. According to editorial preference, these captions may be (1) typed individually on small sheets of paper and attached to illustrations, (2) typed on separate sheets of paper and numbered to correspond to the illustrations, (3) typed in numerical order on a separate sheet headed Explanation of Figures.

If a drawing or other illustration is reproduced from any source, the same obligations must be recognized as in reproducing printed matter. Permission must be obtained and the source acknowledged. If an illustration is altered in any way, it should be designated as "adapted from . . . ," "redrawn from . . . ," or "after . . . ," with the original source indicated.

Figures and tables are usually numbered separately. Their place in copy is indicated by a citation in parentheses giving the figure or table number.

In concluding this discussion of graphic and pictorial illustration in scientific writing, four points should be stressed.

1. Some of the most promising possibilities in illustration lie in new combinations and adaptations of the basic types discussed in this chapter.

2. While the amateur can appreciate and within limits utilize graphic and pictorial illustration, professional scientific illustration is developing rapidly as a specialty for which extended training is required.

3. Visual illustrations, despite their unquestioned value, have certain limitations. Since the particulars to be represented are selected by the writer, illustrations cannot be completely objective. Moreover, illustrations often do not have the precision of complete verbal descriptions and are not to be thought of as a replacement for verbal communication.

[13] "Guide for Authors," following the Index, *Industrial and Engineering Chemistry*, December 1953. Reprinted by permission.

4. A consideration of the relation of visual expression to scientific writing must necessarily be incomplete. The study of this chapter should be supplemented by continued critical observation of the multiple uses of graphic and pictorial illustration.

STUDY SUGGESTIONS

1. One advantage of the photographic record, either still or moving, is that it catches details which may escape the observer while his attentention is directed elsewhere. Cite situations in which this advantage is particularly important.
2. Prepare a table to present data which you have accumulated in the course of a research project. If you have no numerical data available, find a report or newspaper article which includes information which could in your opinion be advantageously presented in a table and prepare a table to present these data.
3. Study the tables in a number of representative scientific textbooks or factual articles. Do you find that the titles and arrangement are in conformity with the practices recommended in the foregoing chapter?
4. Prepare an appropriate graph for each of the groups of data given here:

   Sources of the income of University A: Endowment—40%; Tuition—30%; Tax support—20%; Special gifts—5%; Miscellaneous receipts—5%.

   Changes in the enrollment of University B from 1945-54: 1945—1,000; 1946—1,500; 1947—2,100; 1948—2,750; 1949—2,500; 1950—2,250; 1951—2,000; 1952—2,000; 1953—2,200; 1954—2,300.

5. Examine the illustrations in a group of representative periodicals. What relationships do you find between the subject matter and the types of illustrations? Do you find any illustrations which represent new or unusual combinations of types?
6. A common fault in illustrations, particularly graphs and tables, is that the person preparing the illustration attempts to include too much in a single illustration. Find in a report or other publication an illustration which suffers from this fault. Suggest means of simplifying the illustration or of dividing the subject matter between two or more illustrations.
7. Suggest means of using picture graphs for presenting data on the following subjects: imports of tea, 1945-55; consumption of tea, 1945-55; housing projects in a given area; automobile production 1950-55; circulation of library books during the twelve months of 1954; bank deposits in savings and checking accounts on the first day of each of the past five years.

APPENDIX A

READINGS AND WORD LISTS

The selections which make up this Appendix afford opportunity for additional reading and study in the theory, practices, and types of scientific writing. In content the readings range from the individual scientist's somewhat subjective comments on his work to the altogether impersonal report of a research agency. It is hoped that the selections in the Appendix will stimulate the student to read further in the literature of technology and the sciences.

The selections appear in the order in which the text refers to them. The relevant chapter numbers and titles are indicated at the beginning of each group of selections.

Chapter 2—The Problem Concept

CARBON MONOXIDE POISONING

Claude Bernard, *An Introduction to the Study of Experimental Medicine*, translated by Henry Copley Greene, New York, Abelard-Schuman, Inc., 1949, pp. 159-62

About 1846, I wished to make experiments on the cause of poisoning with carbon monoxide. I knew that this gas had been described as toxic, but I knew literally nothing about the mechanism of its poisoning; I therefore could not have a preconceived opinion. What, then, was to be done? I must bring to birth an idea by making a fact appear, i.e., make another experiment to see. In fact I poisoned a dog by making him breathe carbon monoxide and after death I at once opened his body. I looked at the state of the organs and fluids. What caught my attention at once was that its blood was scarlet in all the vessels, in the veins as well as the arteries, in the right heart as well as in the left. I repeated the experiment on rabbits, birds and frogs, and everywhere I found the same scarlet coloring of the blood. But I was diverted from continuing this investigation, and I kept this observation a long time unused except for quoting it in my course *à propos* of the coloring of blood.

In 1856, no one had carried the experimental question further, and in my course at the Collège de France on toxic and medicinal substances, I again took up the study of poisoning by carbon monoxide which I had begun in 1846. I found myself then in a confused situation, for at this time I already knew that poisoning with carbon monoxide makes the blood scarlet in the whole circulatory system. I had to make hypotheses, and establish a preconceived idea about my first observation so as to go ahead. Now, reflecting on the fact of scarlet blood, I tried to interpret it by my earlier knowledge as to the cause of the color of blood. Whereupon all the following reflections presented themselves to my mind. The scarlet color, said I, is peculiar to arterial blood and connected with the presence of a large proportion of oxygen, while dark coloring belongs with absence of oxygen and presence of a larger proportion of carbonic acid; so the idea occurred to me that carbon monoxide, by keeping venous blood scarlet, might perhaps have prevented the oxygen from changing into carbonic acid in the capillaries. Yet it seemed hard to understand how that could be the cause of death. But still keeping on with my inner preconceived reasoning, I added: If that is true, blood taken from the veins of animals poisoned with carbon monoxide should

be like arterial blood in containing oxygen; we must see if that is the fact.

Following this reasoning, based on interpretation of my observation, I tried an experiment to verify my hypothesis as to the persistence of oxygen in the venous blood. I passed a current of hydrogen through scarlet venous blood taken from an animal poisoned with carbon monoxide, but I could not liberate the oxygen as usual. I tried to do the same with arterial blood; I had no greater success. My preconceived idea was therefore false. But the impossibility of getting oxygen from the blood of a dog poisoned with carbon monoxide was a second observation which suggested a fresh hypothesis. What could have become of the oxygen in the blood? It had not changed into carbonic acid, because I had not set free large quantities of that gas in passing a current of hydrogen through the blood of the poisoned animals. Moreover, that hypothesis was contrary to the color of the blood. I exhausted myself in conjectures about how carbon monoxide could cause the oxygen to disappear from the blood; and as gases displace one another I naturally thought that the carbon monoxide might have displaced the oxygen and driven it out of the blood. To learn this, I decided to vary my experimentation by putting the blood in artificial conditions that would allow me to recover the displaced oxygen. So I studied the action of carbon monoxide on blood experimentally. For this purpose I took a certain amount of arterial blood from a healthy animal; I put this blood on the mercury in an inverted test tube containing carbon monoxide; I then shook the whole thing so as to poison the blood sheltered from contact with the outer air. Then, after an interval, I examined whether the air in the test-tube in contact with the poisoned blood had been changed, and I noted that the air thus in contact with the blood had been remarkably enriched with oxygen, while the proportion of carbon monoxide was lessened. Repeated in the same conditions, these experiments taught me that what had occurred was an exchange, volume by volume, between the carbon monoxide and the oxygen of the blood. But the carbon monoxide, in displacing the oxygen that it had expelled from the blood, remained chemically combined in the blood and could no longer be displaced either by oxygen or by other gases. So that death came through death of the molecules of blood, or in other words by stopping their exercise of a physiological property essential to life.

This last example, which I have very briefly described, is complete; it shows from one end to the other, how we proceed with the experimental method and succeeded in learning the immediate cause of phenomena. To begin with I knew literally nothing about the mechanism of the phenomenon of poisoning with carbon monoxide. I undertook an experiment to see, i.e., to observe. I made a preliminary observation of a special change in the coloring of blood. I interpreted this observation, and I made an hypothesis which proved false. But the experiment pro-

vided me with a second observation about which I reasoned anew, using it as a starting point for making a new hypothesis as to the mechanism, by which the oxygen in the blood was removed. By building up hypotheses, one by one, about the facts as I observed them, I finally succeeded in showing that carbon monoxide replaces oxygen in a molecule of blood, by combining with the substance of the molecule. Experimental analysis, here, has reached its goal. This is one of the cases, rare in physiology, which I am happy to be able to quote. Here the immediate cause of the phenomenon of poisoning is found and is translated into a theory which accounts for all the facts and at the same time includes all the observations and experiments. Formulated as follows, the theory posits the main facts from which all the rest are deduced: Carbon monoxide combines more intimately than oxygen with the hemoglobin in a molecule of blood. It has quite recently been proved that carbon monoxide forms a definite combination with hemoglobin. So that the molecule of blood, as if petrified by the stability of the combination, loses its vital properties. Hence everything is logically deduced: because of its property of more intimate combination, carbon monoxide drives out of the blood the oxygen essential to life; the molecules of blood become inert, and the animal dies, with symptoms of hemorrhage, from true paralysis of the molecules.

But when a theory is sound and indeed shows the real and definite physico-chemical cause of phenomena, it not only includes the observed facts but predicts others and leads to rational applications that are logical consequences of the theory. Here again we meet this criterion. In fact, if carbon monoxide has the property of driving out oxygen by taking its place in combining with a molecule of blood, we should be able to use the gas to analyze the gases in blood, and especially for determining oxygen. From my experiments I deduced this application which has been generally adopted to-day. Applications of this property of carbon monoxide have been made in legal medicine for finding the coloring matter of blood; and from the physiological facts described above we may also already deduce results connected with hygiene, experimental pathology, and notably with the mechanism of certain forms of anemia.

As in every other case, all the deductions from the theory doubtless still require experimental verification; and logic does not suffice. But this is because the conditions in which carbon monoxide acts on the blood may present other complex circumstances and any number of details which the theory cannot yet predict. Otherwise, as we have often said, we could reach conclusions by logic alone, without any need of experimental verifications. Because of possible unforeseen and variable new elements in the conditions of a phenomenon, logic alone can in experimental science never suffice. Even when we have a theory that seems sound, it is never more than relatively sound, and it always includes a certain proportion of the unknown.

THE USEFULNESS OF USELESS KNOWLEDGE

Abraham Flexner, "The Usefulness of Useless Knowledge," *Harper's Magazine*, 179:544-50, October 1939

Is it not a curious fact that in a world steeped in irrational hatreds which threaten civilization itself, men and women—old and young—detach themselves wholly or partly from the angry current of daily life to devote themselves to the cultivation of beauty, to the extension of knowledge, to the cure of disease, to the amelioration of suffering, just as though fanatics were not simultaneously engaged in spreading pain, ugliness, and suffering? The world has always been a sorry and confused sort of place—yet poets and artists and scientists have ignored the factors that would, if attended to, paralyze them. From a practical point of view, intellectual and spiritual life is, on the surface, a useless form of activity, in which men indulge because they procure for themselves greater satisfactions than are otherwise obtainable. In this paper I shall concern myself with the question of the extent to which the pursuit of these useless satisfactions proves unexpectedly the source from which undreamed-of utility is derived.

We hear it said with tiresome iteration that ours is a materialistic age, the main concern of which should be the wider distribution of material goods and worldly opportunities. The justified outcry of those who through no fault of their own are deprived of opportunity and a fair share of worldly goods therefore diverts an increasing number of students from the studies which their fathers pursued to the equally important and no less urgent study of social, economic, and governmental problems. I have no quarrel with this tendency. The world in which we live is the only world about which our senses can testify. Unless it is made a better world, a fairer world, millions will continue to go to their graves silent, saddened, and embittered. I have myself spent many years pleading that our schools should become more acutely aware of the world in which their pupils and students are destined to pass their lives. Now I sometimes wonder whether that current has not become too strong and whether there would be sufficient opportunity for a full life if the world were emptied of some of the useless things that give it spiritual significance; in other words, whether our conception of what is useful may not have become too narrow to be adequate to the roaming and capricious possibilities of the human spirit.

We may look at this question from two points of view: the scientific and the humanistic or spiritual. Let us take the scientific first. I recall a conversation which I had some years ago with Mr. George Eastman on the subject of use. Mr. Eastman, a wise and gentle farseeing man,

gifted with taste in music and art, had been saying to me that he meant to devote his vast fortune to the promotion of education in useful subjects. I ventured to ask him whom he regarded as the most useful worker in science in the world. He replied instantaneously: "Marconi." I surprised him by saying, "Whatever pleasure we derive from the radio or however wireless and the radio may have added to human life, Marconi's share was practically negligible."

I shall not forget his astonishment on this occasion. He asked me to explain. I replied to him somewhat as follows:

"Mr. Eastman, Marconi was inevitable. The real credit for everything that has been done in the field of wireless belongs, as far as such fundamental credit can be definitely assigned to anyone, to Professor Clerk Maxwell, who in 1865 carried out certain abstruse and remote calculations in the field of magnetism and electricity. Maxwell reproduced his abstract equations in a treatise published in 1873. At the next meeting of the British Association Professor H. J. S. Smith of Oxford declared that 'no mathematician can turn over the pages of these volumes without realizing that they contain a theory which has already added largely to the methods and resources of pure mathematics.' Other discoveries supplemented Maxwell's theoretical work during the next fifteen years. Finally in 1887 and 1888 the scientific problem still remaining—the detection and demonstration of the electromagnetic waves which are the carriers of wireless signals—was solved by Heinrich Hertz, a worker in Helmholtz's laboratory in Berlin. Neither Maxwell nor Hertz had any concern about the utility of their work; no such thought ever entered their minds. They had no practical objective. The inventor in the legal sense was of course Marconi, but what did Marconi invent? Merely the last technical detail, mainly the now obsolete receiving device called coherer, almost universally discarded."

Hertz and Maxwell could invent nothing, but it was their useless theoretical work which was seized upon by a clever technician and which has created new means for communication, utility, and amusement by which men whose merits are relatively slight have obtained fame and earned millions. Who were the useful men? Not Marconi, but Clerk Maxwell and Heinrich Hertz. Hertz and Maxwell were geniuses without thought of use. Marconi was a clever inventor with no thought but use.

The mention of Hertz's name recalled to Mr. Eastman the Hertzian waves, and I suggested that he might ask the physicists of the University of Rochester precisely what Hertz and Maxwell had done; but one thing I said he could be sure of, namely, that they had done their work without thought of use and that throughout the whole history of science most of the really great discoveries which had ultimately proved to be beneficial to mankind had been made by men and women who were driven not by the desire to be useful but merely the desire to satisfy their curiosity.

"Curiosity?" asked Mr. Eastman.

"Yes," I replied, "curiosity, which may or may not eventuate in something useful, is probably the outstanding characteristic of modern thinking. It is not new. It goes back to Galileo, Bacon, and to Sir Isaac Newton, and it must be absolutely unhampered. Institutions of learning should be devoted to the cultivation of curiosity and the less they are deflected by considerations of immediacy of application, the more likely they are to contribute not only to human welfare but to the equally important satisfaction of intellectual interest which may indeed be said to have become the ruling passion of intellectual life in modern times."

II

What is true of Heinrich Hertz working quietly and unnoticed in a corner of Helmholtz's laboratory in the later years of the nineteenth century may be said of scientists and mathematicians the world over for several centuries past. We live in a world that would be helpless without electricity. Called upon to mention a discovery of the most immediate and far-reaching practical use we might well agree upon electricity. But who made the fundamental discoveries out of which the entire electrical development of more than one hundred years has come?

The answer is interesting. Michael Faraday's father was a blacksmith; Michael himself was apprenticed to a bookbinder. In 1812, when he was already twenty-one years of age, a friend took him to the Royal Institution where he heard Sir Humphry Davy deliver four lectures on chemical subjects. He kept notes and sent a copy of them to Davy. The very next year, 1813, he became an assistant in Davy's laboratory, working on chemical problems. Two years later he accompanied Davy on a trip to the Continent. In 1825, when he was thirty-four years of age, he became Director of the Laboratory of the Royal Institution where he spent fifty-four years of his life.

Faraday's interest soon shifted from chemistry to electricity and magnetism, to which he devoted the rest of his active life. Important but puzzling work in this field had been previously accomplished by Oersted, Ampère, and Wollaston. Faraday cleared away the difficulties which they had left unsolved and by 1841 had succeeded in the task of induction of the electric current. Four years later a second and equally brilliant epoch in his career opened when he discovered the effect of magnetism on polarized light. His earlier discoveries have led to the infinite number of practical applications by means of which electricity has lightened the burdens and increased the opportunities of modern life. His later discoveries have thus far been less prolific of practical results. What difference did this make to Faraday? Not the least. At no period of his unmatched career was he interested in utility. He was absorbed in disentangling the riddles of the universe, at first chemical riddles, in

later periods, physical riddles. As far as he cared, the question of utility was never raised. Any suspicion of utility would have restricted his restless curiosity. In the end, utility resulted, but it was never a criterion to which his ceaseless experimentation could be subjected.

In the atmosphere which envelops the world to-day it is perhaps timely to emphasize the fact that the part played by science in making war more destructive and more horrible was an unconscious and unintended by-product of scientific activity. Lord Rayleigh, president of the British Association for the Advancement of Science, in a recent address points out in detail how the folly of man, not the intention of the scientists, is responsible for the destructive use of the agents employed in modern warfare. The innocent study of the chemistry of carbon compounds, which has led to infinite beneficial results, showed that the action of nitric acid on substances like benzene, glycerine, cellulose, etc., resulted not only in the beneficent aniline dye industry but in the creation of nitroglycerine, which has uses good and bad. Somewhat later Alfred Nobel, turning to the same subject, showed that by mixing nitroglycerine with other substances, solid explosives which could be safely handled could be produced—among others, dynamite. It is to dynamite that we owe our progress in mining, in the making of such railroad tunnels as those which now pierce the Alps and other mountain ranges; but of course dynamite has been abused by politicians and soldiers. Scientists are, however, no more to blame than they are to blame for an earthquake or a flood. The same thing can be said of poison gas. Pliny was killed by breathing sulphur dioxide in the eruption of Vesuvius almost two thousand years ago. Chlorine was not isolated by scientists for warlike purposes, and the same is true of mustard gas. These substances could be limited to beneficent use, but when the airplane was perfected, men whose hearts were poisoned and whose brains were addled perceived that the airplane, an innocent invention, the result of long disinterested and scientific effort, could be made an instrument of destruction, of which no one had ever dreamed and at which no one had ever deliberately aimed.

In the domain of higher mathematics almost innumerable instances can be cited. For example, the most abstruse mathematical work of the eighteenth and nineteenth centuries was the "Non-Euclidian Geometry." Its inventor, Gauss, though recognized by his contemporaries as a distinguished mathematician, did not dare to publish his work on "Non-Euclidian Geometry" for a quarter of a century. As a matter of fact, the theory of relativity itself with all its infinite practical bearings would have been utterly impossible without the work which Gauss did at Göttingen.

Again, what is known now as "group theory" was an abstract and inapplicable mathematical theory. It was developed by men who were curious and whose curiosity and puttering led them into strange paths;

but "group theory" is to-day the basis of the quantum theory of spectroscopy, which is in daily use by people who have no idea as to how it came about.

The whole calculus of probability was discovered by mathematicians whose real interest was the rationalization of gambling. It has failed of the practical purpose at which they aimed, but it has furnished a scientific basis for all types of insurance, and vast stretches of nineteenth century physics are based upon it. . . .

Let us look in another direction. In the domain of medicine and public health the science of bacteriology has played for half a century the leading role. What is its story? Following the Franco-Prussian War of 1870, the German Government founded the great University of Strasbourg. Its first professor of anatomy was Wilhelm von Waldeyer, subsequently professor of anatomy in Berlin. In his *Reminiscences* he relates that among the students who went with him to Strasbourg during his first semester there was a small, inconspicuous, self-contained youngster of seventeen by name Paul Ehrlich. The usual course in anatomy then consisted of dissection and microscopic examination of tissues. Ehrlich paid little or no attention to dissection, but, as Waldeyer remarks in his *Reminiscences:*

"I noticed quite early that Ehrlich would work long hours at his desk, completely absorbed in microscopic observation. Moreover, his desk gradually became covered with colored spots of every description. As I saw him sitting at work one day, I went up to him and asked what he was doing with all his rainbow array of colors on his table. Thereupon this young student in his first semester supposedly pursuing the regular course in anatomy looked up at me and blandly remarked, '*Ich probiere.*' This might be freely translated, 'I am trying' or 'I am just fooling.' I replied to him, 'Very well. Go on with your fooling.' Soon I saw that without any teaching or direction whatsoever on my part I possessed in Ehrlich a student of unusual quality."

Waldeyer wisely left him alone. Ehrlich made his way precariously through the medical curriculum and ultimately procured his degree mainly because it was obvious to his teachers that he had no intention of ever putting his medical degree to practical use. He went subsequently to Breslau where he worked under Professor Cohnheim, the teacher of our own Dr. Welch, founder and maker of the Johns Hopkins Medical School. I do not suppose that the idea of use ever crossed Ehrlich's mind. He was interested. He was curious; he kept on fooling. Of course his fooling was guided by a deep instinct, but it was a purely scientific, not an utilitarian motivation. What resulted? Koch and his associates established a new science, the science of bacteriology. Ehrlich's experiments were now applied by a fellow student, Weigert, to staining bacteria and thereby assisting in their differentiation. Ehrlich himself developed the

staining of the blood film with the dyes on which our modern knowledge of the morphology of the blood corpuscles, red and white, is based. Not a day passes but that in thousands of hospitals the world over Ehrlich's technic is employed in the examination of the blood. Thus the apparently aimless fooling in Waldeyer's dissecting room in Strasbourg has become a main factor in the daily practice of medicine.

I shall give one example from industry, one selected at random; for there are scores besides. Professor Berl, of the Carnegie Institute of Technology (Pittsburgh) writes as follows:

"The founder of the modern rayon industry was the French Count Chardonnet. It is known that he used a solution of nitro cotton in ether-alcohol, and that he pressed this viscous solution through capillaries into water which served to coagulate the cellulose nitrate filament. After the coagulation, this filament entered the air and was wound up on bobbins. One day Chardonnet inspected his French factory at Besançon. By an accident the water which should coagulate the cellulose nitrate filament was stopped. The workmen found that the spinning operation went much better without water than with water. This was the birthday of the very important process of dry spinning, which is actually carried out on the greatest scale."

III

I am not for a moment suggesting that everything that goes on in laboratories will ultimately turn to some unexpected practical use or that an ultimate practical use is its actual justification. Much more am I pleading for the abolition of the word "use," and for the freeing of the human spirit. To be sure, we shall thus free some harmless cranks. To be sure, we shall thus waste some precious dollars. But what is infinitely more important is that we shall be striking the shackles off the human mind and setting it free for the adventures which in our own day have, on the one hand, taken Hale and Rutherford and Einstein and their peers millions upon millions of miles into the uttermost realms of space and, on the other, loosed the boundless energy imprisoned in the atom. What Rutherford and others like Bohr and Millikan have done out of sheer curiosity in the effort to understand the construction of the atom has released forces which may transform human life; but this ultimate and unforeseen and unpredictable practical result is not offered as a justification for Rutherford or Einstein or Millikan or Bohr or any of their peers. Let them alone. No educational administrator can possibly direct the channels in which these or other men shall work. The waste, I admit again, looks prodigious. It is not really so. All the waste that could be summed up in developing the science of bacteriology is as nothing compared to the advantages which have accrued from the discoveries of Pasteur, Koch, Ehrlich, Theobald Smith, and scores of others—advantages that could never

have accrued if the idea of possible use had permeated their minds. These great artists—for such are scientists and bacteriologists—disseminated the spirit which prevailed in laboratories in which they were simply following the line of their own natural curiosity.

I am not criticising institutions like schools of engineering or law in which the usefulness motive necessarily predominates. Not infrequently the tables are turned, and practical difficulties encountered in industry or in laboratories stimulate theoretical inquiries which may or may not solve the problems by which they were suggested, but may also open up new vistas, useless at the moment, but pregnant with future achievements, practical and theoretical.

With the rapid accumulation of "useless" or theoretic knowledge a situation has been created in which it has become increasingly possible to attack practical problems in a scientific spirit. Not only inventors, but "pure" scientists have indulged in this sport. I have mentioned Marconi, an inventor, who, while a benefactor to the human race, as a matter of fact merely "picked other men's brains." Edison belongs to the same category. Pasteur was different. He was a great scientist; but he was not averse to attacking practical problems—such as the condition of French grapevines or the problems of beer-brewing—and not only solving the immediate difficulty, but also wresting from the practical problem some far-reaching theoretic conclusion, "useless" at the moment, but likely in some unforeseen manner to be "useful" later. Ehrlich, fundamentally speculative in his curiosity, turned fiercely upon the problem of syphilis and doggedly pursued it until a solution of immediate practical use—the discovery of salvarsan—was found. The discoveries of insulin by Banting for use in diabetes and of liver extract by Minot and Whipple for use in pernicious anemia belong in the same category: both were made by thoroughly scientific men, who realized that much "useless" knowledge had been piled up by men unconcerned with its practical bearings, but that the time was now ripe to raise practical questions in a scientific manner.

Thus it becomes obvious that one must be wary in attributing scientific discovery wholly to any one person. Almost every discovery has a long and precarious history. Someone finds a bit here, another a bit there. A third step succeeds later and thus onward till a genius pieces the bits together and makes the decisive contribution. Science, like the Mississippi, begins in a tiny rivulet in the distant forest. Gradually other streams swell its volume. And the roaring river that bursts the dikes is formed from countless sources.

I cannot deal with this aspect exhaustively, but I may in passing say this: over a period of one or two hundred years the contributions of professional schools to their respective activities will probably be found to lie, not so much in the training of men who may to-morrow become practical engineers or practical lawyers or practical doctors, but rather in

the fact that even in the pursuit of strictly practical aims an enormous amount of apparently useless activity goes on. Out of this useless activity there come discoveries which may well prove of infinitely more importance to the human mind and to the human spirit than the accomplishment of the useful ends for which the schools were founded.

The considerations upon which I have touched emphasize—if emphasis were needed—the overwhelming importance of spiritual and intellectual freedom. I have spoken of experimental science; I have spoken of mathematics; but what I say is equally true of music and art and of every other expression of the untrammeled human spirit. The mere fact that they bring satisfaction to an individual soul bent upon its own purification and elevation is all the justification that they need. And in justifying these without any reference whatsoever, implied or actual, to usefulness we justify colleges, universities, and institutes of research. An institution which sets free successive generations of human souls is amply justified whether or not this graduate or that makes a so-called useful contribution to human knowledge. A poem, a symphony, a painting, a mathematical truth, a new scientific fact, all bear in themselves all the justification that universities, colleges, and institutes of research need or require.

The subject which I am discussing has at this moment a peculiar poignancy. In certain large areas—Germany and Italy especially—the effort is now being made to clamp down the freedom of the human spirit. Universities have been so reorganized that they have become tools of those who believe in a special political, economic, or racial creed. Now and then a thoughtless individual in one of the few democracies left in this world will even question the fundamental importance of absolutely untrammeled academic freedom. The real enemy of the human race is not the fearless and irresponsible thinker, be he right or wrong. The real enemy is the man who tries to mold the human spirit so that it will not dare to spread its wings, as its wings were once spread in Italy and Germany, as well as in Great Britain and the United States.

This is not a new idea. It was the idea which animated von Humboldt when, in the hour of Germany's conquest by Napoleon, he conceived and founded the University of Berlin. It is the idea which animated President Gilman in the founding of the Johns Hopkins University, after which every university in this country has sought in greater or less degree to remake itself. It is the idea to which every individual who values his immortal soul will be true whatever the personal consequences to himself. Justification of spiritual freedom goes, however, much farther than originality whether in the realm of science or humanism, for it implies tolerance throughout the range of human dissimilarities. In the face of the history of the human race what can be more silly or ridiculous than likes or dislikes founded upon race or religion? Does humanity want symphonies and paintings and profound scientific truth, or does it want

Christian symphonies, Christian paintings, Christian science, or Jewish symphonies, Jewish paintings, Jewish science, or Mohammedan or Egyptian or Japanese or Chinese or American or German or Russian or Communist or Conservative contributions to and expressions of the infinite richness of the human soul?

DISCOVERIES WITH THE NEW FORMULA FOR SILVER IMPREGNATION

Santiago Ramón y Cajal, *Recollections of My Life*,
translated by E. Horne Craigie,
Memoirs of the American Philosophical Society,
Vol. VIII, Philadelphia, 1937, Part II, pp. 526-27

It is a commonplace fact that scientific discoveries are a function of the methods used. A strictly differential technique having appeared, there follow immediately, in a logical series and in an almost automatic fashion, unlooked for clarifications of problems formerly insoluble or incompletely settled. And if this is true in respect of all the natural sciences, it is so most conspicuously in the realms of histology. For the histologist, every advance in staining technique is something like the acquisition of a new sense directed towards the unknown. As if nature had determined to hide from our eyes the marvellous structure of its organization, the cell, the mysterious protagonist of life, is hidden obstinately in the double invisibility of smallness and homogeneity. Structures of formidable complexity appear under the microscope with the colourlessness, the uniformity of refractive index, and the simplicity of architecture of a mass of jelly. The other natural sciences are more fortunate in that they work with objects of study which are directly accessible to the senses. Only histology and bacteriology are obliged to fulfil the preliminary and difficult task of making visible their special objects of study before they can commence the work of analysis. And in such a severe campaign they have to struggle, as I have already said, with two adversaries; smallness and transparency. The histologist can advance in the knowledge of the tissues only by impregnating or tinting them selectively with various hues which are capable of making the cells stand out energetically from an uncoloured background. In this way, the bee-hive of the cells is revealed to us unveiled; it might be said that the swarm of transparent and invisible infusorians is transformed into a flock of painted butterflies.

Chapter 3—Definition and Terminology

1. Prefixes of Greek and Latin Origin

A prefix is one or more syllables, usually an adverb or a preposition, placed before a word or root to modify its meaning. Adding the prefix may result in a different spelling of the prefix or of the root or stem because of the demands of euphony. For example, *addict*, *affix*, and *assimilate* all come from Latin words originally formed by use of the prefix *ad*.

Prefix	*From*	*Meaning*	*Examples*
a, ab	L.	away, from	abduct aberration abnormal
ad	L.	to, toward	adhesion addict affix assimilate
ambi	L.	both	ambidextrous
a, an	G.	not, without	anarchy anemia anhydrous atypical
ana	G.	back, up, apart	anachronism analysis
ante	L.	before	antecedent anterior (comparative)
amphi	G.	around, both	amphibian amphitheater
bi	L.	two, twice	bicycle biped bisect
cata, cath, cat	G.	down, in accordance with	cataclinal catalysis cataclysm cataract catarrh catastrophe
contra	L.	against	contradict contraindicate contravene
cum, co, cog, col, com, con, cor	L.	with, together	coincide collect congenital correlate compound

Prefix	*From*	*Meaning*	*Examples*
de	L.	down, from, away	decompose dehydrate decline detoxify
di, dis	G.	twice	diacid dibasic dimorphism
dia	G.	through, across	diagram diameter diaphragm diaphragmatic
dys	G.	bad, hard, ill	dyspepsia
e, ef, ex	L.	out of, away from	eject evolve exclude exhaust
ec, ex	G.	out of	eccentric eczema
ecto	G.	outside, without	ectoblast ectoderm
endo	G.	within	endoblast endoderm
eu	G.	well, good	eulogy euphemism euphony
extra	L.	beyond, outside of	extralateral extraneous extraordinary extroversion
hyper	G.	over	hyperacidity hyperbole
hypo	G.	under	hypodermic hypotenuse hypothesis hypothyroid
in	L.	in, into	incision incline indigenous induce influx
infra	L.	below	infracostal infrared
inter	L.	between	intercostal interfere
intra, intro	L.	within	intracellular intravenous
iso	G.	equal, same	isosceles isotherm
macro	G.	large	macrocosm macrocyte

Prefix	*From*	*Meaning*	*Examples*
meso	G.	middle	mesoblast mesoderm
meta	G.	after, beyond, with	metamorphosis metaphor metaphysical
non	L.	not	nonconductor nondescript
para	G.	beside, against	parable paragraph parallel
per	L.	through (intensive)	perdurable perforate permanent
peri	G.	around	perimeter periosteal periscope
poly	G.	many	polygamy polyhedron
post	L.	after	posterior (comparative) postmortem
pre	L.	before	premonitory prefix preface prenatal
pro	G.	before	proboscis prodromal program
re	L.	again, back	reaction refract restore
retro	L.	behind, backward	retroactive retrogression retrospective
sub	L.	under	subdivision subdiaphragmatic subnormal submerge substructure
super, supra	L.	over, above	superimpose supernatural superstructure suprarenal
sur	L.	above, over	surtax surrealistic survey
trans	L.	across, through	translucent transparent transfuse transverse
ultra	L.	beyond, excessively	ultramicroscopic

2. Prefixes Indicating Number

Number	*Latin*	*Greek*
half	semi (semicircle)	hemi (hemisphere)
one	uni (unilateral)	mono (monopoly)
two	bi (bisect)	di (dioxide)
three	tri (triangle)	tri (tricycle)
four	quadr (quadrangle)	tetra (tetrachloride)
five	penta (pentameter)	penta (pentagon)
six	sex (sexpartite)	hexa (hexagon)
seven	sept (septuplet)	hept (heptagon)
eight	oct (octave)	oct (octagon)
nine	nona (nonary)	ennea (ennead)
ten	dec (decennial)	dec (decalogue)
one hundred	centi (centimeter)	hecto (hectogram)
thousand	milli (millimeter)	kilo (kilogram)

3. Suffixes of Greek and Latin Origin

A suffix is one or more syllables added after a word or root to modify its meaning.

Suffix	*From*	*Meaning*	*Examples*
ant, ent	L.	in adjectives, with the force of the present participle; in nouns, one who or that which	errant defiant claimant quadrant radiant servant solvent
arium	L.	place for	aquarium solarium
ate	L.	from past participle of first Latin conjugation; used in forming adjectives, nouns, and causative verbs	temperate fascinate perforate precipitate sulphate
ation, tion	L.	act, state, or quality of; that which	fermentation formation stagnation suffocation
cle, cule	L.	small	particle molecule pedicel pedicle
esce, escent	L.	becoming	adolescent effervescent obsolescent

Suffix	*From*	*Meaning*	*Examples*
ectomy	G.	cutting out	tonsillectomy
fy	L.	make	mortify pacify solidify qualify
ia	G.	noun ending	phobia neuralgia
ic	G.	of the nature of, pertaining to	dramatic rhetoric
ine	L.	pertaining to	alkaline bovine canine
ism	G.	act, condition, characteristic or doctrine of	colloquialism Darwinism stoicism
ist	G.	one who	atheist botanist physicist
itis	G.	inflammation of	bronchitis neuritis
ize	G.	make like, subject to	dramatize plagiarize
oid	G.	like, in the form of	asteroid anthropoid
ology	G.	theory or science of	anthropology entomology etymology pathology psychology
or	L.	state or quality of, one who, that which	error actor survivor doctor elevator
osis	G.	condition or process; medical, often abnormal	metamorphosis toxicosis tuberculosis

4. Combining Forms

A combining form is a word or word element (root or stem) used with one or more other words or elements to form a compound. Unlike prefixes and suffixes, combining forms are not restricted to the beginning or the end of the completed word. They are usually nouns or adjectives, and each one contributes a concrete or specific idea to the compound. For example, *autohemotherapy* is made up of three elements—*auto,* self; *hemo,* blood; *therapy,* treatment; the term means treatment by the injection of the patient's own blood.

Form	*From*	*Meaning*	*Examples of Use*	
agon	G.	combat	agony protagonist	antagonist
anthro	G.	man	anthropogenesis anthropology	anthropoid anthropomorphic
algia	G.	pain	analgesic	neuralgia
archa	G.	ancient	archaic	archaeology
bibl	G.	book	Bible	bibliography
bio	G.	life	biology	symbiosis
blast	G.	shoot, germ	blastocyte blastoma	blastoderm ectoblast
cardi	G.	heart	cardiograph	endocarditis
caud	L.	tail	caudad caudal	caudate
cephal	G.	head	cephalad encephalitis	cephalic hydrocephalic
chrom	G.	color	chromatic	
chronos	G.	time	chronology chronic	anachronism chronograph
cosm	G.	universe	cosmic cosmos	cosmopolite
crit	G.	judge	critic	criterion
cyt	G.	originally hollow jar, urn; cell	cytology	cytoblast
dent	L.	tooth	dental	dentate
derm	G.	skin	dermal dermatitis	epidermis ectoderm
ego	L.	I	ego egocentric	egotist
esthesia	G.	sensation	anesthesia paresthesia	aesthetic
gam	G.	marriage	monogamy	polygamy
gen	G.	birth, descent	genealogy	parthenogenesis (cf. Parthenon)
glossa	G.	tongue	glossal glossitis	glossalgia glossary (through Latin, glossa—a difficult word)
graph	G.	write	geography	telegraph
hemo	G.	blood	hemoglobin hemophilia	hemolytic hemorrhage
hetero	G.	different	heterodox heterogony	heterogeneous heterogenous
homo (cf. hetero)	G.	the same	homogeneous homogeny	homology homozygote
hydr	G.	water	hydrogen hydrant hydraulic	hydrophobia hydrate
iatr	G.	healing, medical care	psychiatry	pediatrics

Form	*From*	*Meaning*	*Examples of Use*	
idio	G.	one's own, peculiar	idiosyncrasy	idiopathic
kine	G.	motion	kinetic cinema	kinesthesia
micro	G.	small	microscope	microcosm
morpho	G.	form	morphology morphogenesis	amorphous anthropomorphic
necr	G.	death, dead	necrology necrosis	necropolis necrotic
neo	G.	new	neoclassic neoplasm	neolithic
neur	G.	nerve	neuralgia neurosis	neuritis neural
odont	G.	tooth	orthodontist	orthodontia
ophthalm	G.	eye	ophthalmology	
ornith	G.	bird	ornithology	
ortho	G.	correct, straight	orthodox orthodontia	orthography orthopedic
pan	G.	all	panacea	
pathos	G.	suffering, disease	pathognomonic pathos	pathology
ped (pes, pedis—foot)	L.	foot	pedal	biped
ped (pais—child)	G.	child	pediatrics	pedagogue
phil	G.	love	philosophy	eosinophil
phobia	G.	fear, often implying dislike or aversion	hydrophobia	
phon	G.	sound, voice	phonetic	telephone
proto	G.	first	protoplasm prototype	protozoa
pneu (pnea)	G.	air	pneumatic	
pseudo	G.	false	pseudopod	pseudonym
pyo	G.	pus	pyogenic	pyosis
pyr	G.	fire	pyromaniac pyretic	pyrotechnic
schi	G.	split	schism	schizoid
tax	G.	order	taxonomy	syntax
therm	G.	heat	thermal	thermometer
tom	G.	cut (ectomy—cutting out)	anatomy	microtome
zo	G.	animal	zoology	

5. *Plural Forms*

A number of English words borrowed from Greek and Latin retain the plural forms of their original declensions. Writers of science have been somewhat more conservative than writers in general about adopting Eng-

lish plurals even when they are acceptable. Usage varies in different fields, but the writer should know the plural forms commonly used. This list of plurals is not intended to be inclusive but represents a number of Greek and Latin declensions.

Singular	*Plural*
alga	algae
alumna	alumnae
alumnus	alumni
analysis	analyses
apparatus	apparatus, apparatuses
appendix	appendixes, appendices
automaton	automatons, automata
bacterium	bacteria
cortex	cortices
criterion	criteria
curriculum	curricula
datum	data
differentia	differentiae
focus	focuses, foci
index	indexes, indices
medium	media
memorandum	memoranda
nucleus	nuclei
phenomenon	phenomena
radius	radii, radiuses
stigma	stigmata, stigmas
stimulus	stimuli
synthesis	syntheses
thesis	theses
vortex	vortexes, vortices

6. *Words and Terms Derived from Greek and Latin Proper Names*

A number of scientific terms and words frequently used in scientific writing are derived from the names of characters in Greek and Latin myths. Most of these words have come down to us from the days when every scientist was learned in the classics.

Name	*Derivative*
Arachne	arachnid
	arachnoid
Atlas	atlas
Chaos	chaos
	chaotic

Name	*Derivative*
Chronos (Cronus)	chronic
	chronicle
	chronological
	chronometer
Echo	echo
Eros	erotic
Fauna	fauna
Flora	flora
Gaea	geode
	geology
	geometry
Helios	heliograph
	heliotrope
	heliotropism
	helium
Hercules	herculean
Hyacinth	hyacinth
Hymen	hymeneal
Janus	January
Mercury	mercury
Morpheus	morphine
Narcissus	narcissus
	the narcissus complex
Nemesis	nemesis
Oedipus	the Oedipus complex
Pluto	Plutonic
Plutus	plutocracy
Proteus	protean
Psyche	psychiatry
	psychic
	psychology
Tantalus	tantalize
	tantalum
Terminus	terminus
Uranus	Uranus
	uranium
Vulcan	vulcanite
	vulcanize

Chapter 4—Collecting Data

IN WHAT FORM DO YOU LIKE TO FIND LITERATURE CITATIONS?

The American Institute of Biological Sciences,
The A.I.B.S. Bulletin, 1(5):21, October 1951

Most biologists agree that uniformity in citations is preferable to the great variations now encountered from one publication to another. Based on the short vote taken in connection with the A.I.B.S. Columbus meeting of last year, and a more recent sample vote among certain editors and librarians, the A.I.B.S. Publications Committee is preparing a guide for literature citations. To approach more nearly what readers desire, the Committee is sending out this ballot to secure a vote on the more critical items.

Probably no one system will meet the needs of all groups. The results of this vote, however, will indicate how most people feel about certain critical points.

Will you please help by marking the appropriate places to indicate your preferences.

I. *In which sequence do you prefer citations to literature?* [*Please check preferences*]
   A. Alphabetical order according to authorship _____
   B. Numbered in the order of appearance in text _____

II. *Authorship*
   A. Do you like the initials of second and subsequent authors to be reversed or in natural order? Examples:
      Smith, R. E., Jones, A. J., and Brown, E. F. _____
      Smith, R. E., A. J. Jones, and E. F. Brown _____
   B. Do you prefer "and" or "&"? Examples:
      Smith, R. E., and A. J. Jones _____
      Smith, R. E., & A. J. Jones _____
   C. Do you prefer a woman's name spelled out or merely with an initial? Examples:
      Johnson, Barbara _____
      Johnson, B. _____
   D. Shall names appear exactly as on the publication or be abbreviated to initials? Examples:

Moore, George W., and Howard L. Hansen ______
Moore, G. W., and H. L. Hansen ______

E. With more than two names, should all be given or only the first name followed by *et al.*? Examples:
Smith, R. E., A. J. Jones, and E. F. Brown ______
Smith, R. E., *et al.* ______

III. *Titles of articles or books*
A. Do you want titles included? Yes______ No______
B. If you mark A "yes," should long titles be shortened? Yes______ No______

IV. *Abbreviations of journals*
Which list of abbreviations do you prefer?
A. Chemical Abstracts ______
B. Index of American Botanical Literature ______
C. International Catalog ______
D. U. S. Department of Agriculture ______
E. World List ______
F. Other List (please name it) ______

V. *Position of date*
Where should the date appear?
A. At the end. Example:
Cook, M. T. The diseases of tropical plants. 317 p. London, 1913 ______
B. Following the authorship. Example:
Cook, M. T. 1913. The diseases of tropical plants. 317 p. London ______

VI. *Illustrations*
Shall the illustrations be indicated?
A. No mention of illustrations ______
B. The simple abbreviation "illus." ______
C. Details, such as "2 pl., 5 figs." ______

VII. *Publisher of a book and his location*
Shall the publisher be included as well as the place of publication? Examples:
A. McGraw-Hill, New York ______
B. New York ______

Please indicate any special interest you may have in these questions, and add your further comments.

Please tear out this ballot and mail before November 15 to A. J. Riker, Chairman, A.I.B.S. Publications Committee, Dept. Plant Pathology, University of Wisconsin, Madison 6, Wisconsin.

GETTING AT THE TRUTH

Marchette Chute, "Getting at the Truth,"
The Saturday Review, 36(38):11-12, September 19, 1953

This is a rather presumptuous title for a biographer to use, since truth is a very large word. In the sense that it means the reality about a human being it is probably impossible for a biographer to achieve. In the sense that it means a reasonable presentation of all the available facts it is more nearly possible, but even this limited goal is harder to reach than it appears to be. A biographer needs to be both humble and cautious when he remembers the nature of the material he is working with, for a historical fact is rather like the flamingo that Alice in Wonderland tried to use as a croquet mallet. As soon as she got its neck nicely straightened out and was ready to hit the ball, it would turn and look at her with a puzzled expression, and any biographer knows that what is called a "fact" has a way of doing the same.

Here is a small example. When I was writing my forthcoming biography, "Ben Jonson of Westminster," I wanted to give a paragraph or two to Sir Philip Sidney, who had a great influence on Jonson. No one thinks of Sidney without thinking of chivalry, and to underline the point I intended to use a story that Sir Fulke Greville told of him. Sidney died of gangrene, from a musket shot that shattered his thigh, and Greville says that Sidney failed to put on his leg armor while preparing for battle because the marshal of the camp was not wearing leg armor and Sidney was unwilling to do anything that would give him a special advantage.

The story is so characteristic both of Sidney himself and of the misplaced high-mindedness of late Renaissance chivalry that I wanted to use it, and since Sir Fulke Greville was one of Sidney's closest friends the information seemed to be reliable enough. But it is always well to check each piece of information as thoroughly as possible and so I consulted another account of Sidney written by a contemporary, this time a doctor who knew the family fairly well. The doctor, Thomas Moffet, mentioned the episode but he said that Sidney left off his leg armor because he was in a hurry.

The information was beginning to twist in my hand and could no longer be trusted. So I consulted still another contemporary who had mentioned the episode, to see which of the two he agreed with. This was Sir John Smythe, a military expert who brought out his book a few years after Sidney's death. Sir John was an old-fashioned conservative who advocated the use of heavy armor even on horseback, and he deplored the current craze for leaving off leg protection, "the imitating of

which . . . cost that noble and worthy gentleman Sir Philip Sidney his life."

So here I was with three entirely different reasons why Sidney left off his leg armor, all advanced by careful writers who were contemporaries of his. The flamingo had a legitimate reason for looking around with a puzzled expression.

The only thing to do in a case like this is to examine the point of view of the three men who are supplying the conflicting evidence. Sir Fulke Greville was trying to prove a thesis: that his beloved friend had an extremely chivalric nature. Sir John Smythe also was trying to prove a thesis: that the advocates of light arming followed a theory that could lead to disaster. Only the doctor, Thomas Moffet, was not trying to prove a thesis. He was not using his own explanation to reinforce some point he wanted to make. He did not want anything except to set down on paper what he believed to be the facts; and since we do not have Sidney's own explanation of why he did not put on leg armor, the chances are that Dr. Moffet is the safest man to trust.

For Moffet was without desire. Nothing can so quickly blur and distort the facts as desire—the wish to use the facts for some purpose of your own—and nothing can so surely destroy the truth. As soon as the witness wants to prove something he is no longer impartial and his evidence is no longer to be trusted.

Chapter 5—Analysis: Methods and Applications

Reprinted by permission of the publishers from George Howard Parker, *The World Expands*, pp. 34-37, Cambridge, Harvard University Press. Copyright 1946, by the President and Fellows of Harvard College

Thus I became a part of the family at the Academy of Natural Sciences. My duties were to clean, order, and arrange the collection of butterflies, not a very large one, belonging to the institution and to help any visitor who might wish special information about insects. . . .

As a member of the Academy's family, I was thrown with an interesting group of men. I was by far the youngest of them all, but I was invariably treated most kindly. . . . The younger members of this group commonly brought their luncheons with them to the Academy. At the midday hour we retired to a basement room where we ate our repast around a table which served in several ways as our center of interest. At about this

period two books had appeared that made a special appeal to young zoologists. One of these was Mivart's *Cat*, and the other was Flower's *Osteology of the Mammalia.* These books were eagerly read by us and kept within easy reach for reference. As a result of studying them we had all indulged freely in making skeletons—cats, turtles, dogs, birds, snakes, frogs, and even fishes, in part or as wholes fell into the boiling pot and came out clean bones. Many of these thus prepared, mostly as separate specimens, found their way into a large wooden box that stood by our lunch table. During the time of our repast it was usual for one of us to reach a hand into the bone-box, bring out as chance would have it a single bone and put it in the middle of the table for identification. Was it from a bird or from a mammal or from some other creature? If a vertebra, which face was front, which back, which above and which below? Woe be to him who did not know the law of the zygapophyses! Do prezygapophyses face upward or down? And so on through the luncheon which thus became food for the soul as well as for the body. The end of the meal was usually followed by a brief trip to the hall of the museum where a disputed point could be settled by reference to a mounted skeleton. By this kind of exercise we came to know bones as we did our alphabet.

When I went to Harvard I took a course in my second year on cat anatomy under Dr. Walter Faxon and in a joking way our instructor put a cat bone on a laboratory table, around which half a dozen of us had gathered, and asked what bone it was. The query was put to us in a challenging spirit. Most of the group gave up, but by the mere accident of my early training I felt at home with such a question. When the query was put to me I declared for the left navicular of the cat. We took the loose bone for final identification to a mounted cat skeleton and there the bone was in the cat's instep on the left side. Dr. Faxon looked at me in surprise, in fact he seemed almost appalled, till I told him of the training that I had been through. He then quickly saw that my kind of genius was all perspiration and no inspiration. Nevertheless, he was always thereafter more considerate of me and took a special interest in showing me the historical New England countryside in the neighborhood of Cambridge and Boston, for he was a born antiquarian.

Beside the younger men in the Academy's family, there were also scientific worthies of greater maturity but no less friendliness. The oldest of these was Titian Peale, whose artistic instincts led him to prepare beautiful illustrations of the American butterflies and moths which unfortunately never saw the light. Then there was the anatomist, Dr. Harrison Allen, a student of bats, who gave me my first lesson in anatomy by showing me how to dissect a snapping turtle. Of equal interest were the two notable students of American beetles, Dr. G. H. Horn and Dr. John L. LeConte, both much concerned with the collections of the Ameri-

can Entomological Society then stored in rooms at the Academy. We saw every week or so the Reverend H. C. McCook, who was at that time in the midst of his studies on the habits of American ants; and George W. Tryon, Jr., the curator of the Academy's collection of shells, was well started at this period on his colossal monograph of the shells of the world. These men and many others were among those who might be called the zoologically inclined members of the Academy's household, but beside them this institution found place for numerous botanists, geologists, mineralogists, and other natural historians whose total interests seemed to cover every aspect of Nature.

Perhaps possessed of wider interests than any of those already mentioned, and certainly most widely known of all in the world of Science, was Dr. Joseph Leidy. When I first came to the Academy, he was chairman of its board of curators and before I left that institution he had become its revered president. As Jessup students we came directly under Dr. Leidy's supervision. It was his habit to come to the Academy about once a week during daytime hours, and at such times we were always free to bring to him any difficulties that had arisen in our work. These matters he talked over with us with kindly consideration and interest. He knew us well enough to call us by our given names, which emphasized our apprentice to master relationship.

As I look back on those brief but not infrequent meetings with Dr. Leidy, I am impressed with what they really meant for me. Though a most distinguished scholar in the broad field of natural history, his remarks on any subject were in language so simple that anyone could understand, and though he often used technical terms he used them with a word of explanation which made them at once plain and clear. I have elsewhere described how he once spoke to a group of schoolchildren, on the form of the human skull; a strange subject to introduce to children, and yet he did it in such a direct and simple manner that in a few minutes he had all the youngsters fully aroused and eager to grasp all that he described to them. His talk was especially instructive to me, as I listened from the outskirts of the group, to see how he used technical terms. He remarked when he came to the foramen magnum that this was the largest opening in the skull and that it was the aperture for the connection between the brain and the spinal cord. He then went on to say that to call it by its technical name seemed very learned, but to a Roman the words foramen magnum meant merely a big hole. Pedantry never found a place with Dr. Leidy.

Warren Weaver, "Science and Complexity," *American Scientist,* 36:537-38, October 1948

Subsequent to 1900 and actually earlier, if one includes heroic pioneers such as Josiah Willard Gibbs, the physical sciences developed an attack on nature of an essentially and dramatically new kind. Rather than study problems which involved two variables or at most three or four, some imaginative minds went to the other extreme, and said: "Let us develop analytical methods which can deal with two billion variables." That is to say, the physical scientist, with the mathematicians often in the vanguard, developed powerful techniques of probability theory and of statistical mechanics to deal with what may be called problems of *disorganized complexity.*

This last phrase calls for explanation. Consider first a simple illustration in order to get the flavor of the idea. The classical dynamics of the nineteenth century was well suited for analyzing and predicting the motion of a single ivory ball as it moves about on a billiard table. In fact, the relationship between positions of the ball and the times at which it reaches these positions forms a typical nineteenth-century problem of simplicity. One can, but with a surprising increase in difficulty, analyze the motion of two or even of three balls on a billiard table. There has been, in fact, considerable study of the mechanics of the standard game of billiards. But, as soon as one tries to analyze the motion of ten or fifteen balls on the table at once, as in pool, the problem becomes unmanageable, not because there is any theoretical difficulty, but just because the actual labor of dealing in specific detail with so many variables turns out to be impractical.

Imagine, however, a large billiard table with millions of balls rolling over its surface, colliding with one another and with the side rails. The great surprise is that the problem now becomes easier, for the methods of statistical mechanics are applicable. To be sure the detailed history of one special ball can not be traced, but certain important questions can be answered with useful precision, such as: On the average how many balls per second hit a given stretch of rail? On the average how far does a ball move before it is hit by some other ball? On the average how many impacts per second does a ball experience?

Earlier it was stated that the new statistical methods were applicable to problems of disorganized complexity. How does the word "disorganized" apply to the large billiard table with the many balls? It applies because the methods of statistical mechanics are valid only when the balls are distributed, in their positions and motions, in a helter-skelter, that is to say a disorganized, way. For example, the statistical methods would

not apply if someone were to arrange the balls in a row parallel to one side rail of the table, and then start them all moving in precisely parallel paths perpendicular to the two in which they stand. Then the balls would never collide with each other nor with two of the rails, and one would not have a situation of disorganized complexity.

From this illustration it is clear what is meant by a problem of disorganized complexity. It is a problem in which the number of variables is very large, and one in which each of the many variables has a behavior which is individually erratic, or perhaps totally unknown. However, in spite of this helter-skelter, or unknown, behavior of all the individual variables, the system as a whole possesses certain orderly and analyzable average properties.

A wide range of experience comes under the label of disorganized complexity. The method applies with increasing precision when the number of variables increases. It applies with entirely useful precision to the experience of a large telephone exchange, in predicting the average frequency of calls, the probability of overlapping calls of the same number, etc. It makes possible the financial stability of a life insurance company. Although the company can have no knowledge whatsoever concerning the approaching death of any one individual, it has dependable knowledge of the average frequency with which deaths will occur.

This last point is interesting and important. Statistical techniques are not restricted to situations where the scientific theory of the individual events is very well known, as in the billiard example where there is a beautifully precise theory for the impact of one ball on another. This technique can also be applied to situations, like the insurance example, where the individual event is as shrouded in mystery as is the chain of complicated and unpredictable events associated with the accidental death of a healthy man.

The examples of the telephone and insurance companies suggest a whole array of practical applications of statistical techniques based on disorganized complexity. In a sense they are unfortunate examples, for they tend to draw attention away from the more fundamental use which science makes of these new techniques. The motions of the atoms which form all matter, as well as the motions of the stars which form the universe, come under the range of these new techniques. The fundamental laws of heredity are analyzed by them. The laws of thermodynamics, which describe basic and inevitable tendencies of all physical systems, are derived from statistical considerations. The entire structure of modern physics, our present concept of the nature of the physical universe, and of the accessible experimental facts concerning it rest on these statistical concepts. Indeed, the whole question of evidence and the way in which knowledge can be inferred from evidence are now recognized to depend on these same statistical ideas, so that probability notions are essential to any theory of knowledge itself.

Chapter 6—Interpretation: Applying the Principles of Logic

Francis Darwin, editor, *The Life and Letters of Charles Darwin*, New York, D. Appleton and Company, 1925, Vol. I, pp. 67-68

From September 1854 I devoted my whole time to arranging my huge pile of notes, to observing, and to experimenting in relation to the transmutation of species. During the voyage of the *Beagle* I had been deeply impressed by discovering in the Pampean formation great fossil animals covered with armour like that on the existing armadillos; secondly, by the manner in which closely allied animals replace one another in proceeding southwards over the Continent; and thirdly, by the South American character of most of the productions of the Galapagos archipelago, and more especially by the manner in which they differ slightly on each island of the group; none of the islands appearing to be very ancient in a geological sense.

It was evident that such facts as these, as well as many others, could only be explained on the supposition that species gradually become modified; and the subject haunted me. But it was equally evident that neither the action of the surrounding conditions, nor the will of the organisms (especially in the case of plants) could account for the innumerable cases in which organisms of every kind are beautifully adapted to their habits of life—for instance, a woodpecker or a tree-frog to climb trees, or a seed for dispersal by hooks or plumes. I had always been much struck by such adaptations, and until these could be explained it seemed to me almost useless to endeavour to prove by indirect evidence that species have been modified.

After my return to England it appeared to me that by following the example of Lyell in Geology, and by collecting all facts which bore in any way on the variation of animals and plants under domestication and nature, some light might perhaps be thrown on the whole subject. My first note-book was opened in July 1837. I worked on true Baconian principles, and without any theory collected facts on a wholesale scale, more especially with respect to domesticated productions, by printed enquiries, by conversation with skilful breeders and gardeners, and by extensive reading. When I see the list of books of all kinds which I read and abstracted, including whole series of Journals and Transactions, I am surprised at my industry. I soon perceived that selection was the keystone of man's success in making useful races of animals and plants. But how selection could be applied to organisms living in a state of nature remained for some time a mystery to me.

Julian S. Huxley, *Evolution: The Modern Synthesis,* New York, Harper & Brothers, 1942, pp. 13-14. Copyright 1942 by Julian S. Huxley

Biology at the present time is embarking upon a phase of synthesis after a period in which new disciplines were taken up in turn and worked out in comparative isolation. Nowhere is this movement towards unification more likely to be valuable than in this many-sided topic of evolution; and already we are seeing the first-fruits in the re-animation of Darwinism.

By Darwinism I imply that blend of induction and deduction which Darwin was the first to apply to the study of evolution. He was concerned both to establish the fact of evolution and to discover the mechanism by which it operated; and it was precisely because he attacked both aspects of the problem simultaneously, that he was so successful. On the one hand he amassed enormous quantities of facts from which inductions concerning the evolutionary process could be drawn; and on the other, starting from a few general principles, he deduced the further principle of natural selection.

It is as well to remember the strong deductive element in Darwinism. Darwin based his theory of natural selection on three observable facts of nature and two deductions from them. The first fact is the tendency of all organisms to increase in a geometrical ratio. The tendency of all organisms to increase is due to the fact that offspring, in the early stages of their existence, are always more numerous than their parents; this holds good whether reproduction is sexual or asexual, by fission or by budding, by means of seeds, spores, or eggs.* The second fact is that, in spite of this tendency to progressive increase, the numbers of a given species actually remain more or less constant.

The first deduction follows. From these two facts he deduced the struggle for existence. For since more young are produced than can survive, there must be competition for survival. In amplifying his theory, he extended the concept of the struggle for existence to cover reproduction. The struggle is in point of fact for survival of the stock; if its survival is aided by greater fertility, an earlier breeding season, or other reproductive function, these should be included under the same head.

Darwin's third fact of nature was variation: all organisms vary appreciably. And the second and final deduction, which he deduced from the first deduction and the third fact, was Natural Selection. Since there is a struggle for existence among individuals, and since these individuals

* The only exception, so far as I am aware, is to be found in certain human populations which fall far short of replacing themselves.

are not all alike, some of the variations among them will be advantageous in the struggle for survival, others unfavourable. Consequently, a higher proportion of individuals with favourable variations will on the average survive, a higher proportion of those with unfavourable variations will die or fail to reproduce themselves. And since a great deal of variation is transmitted by heredity, these effects of differential survival will in large measure accumulate from generation to generation. Thus natural selection will act constantly to improve and to maintain the adjustment of animals and plants to their surroundings and their way of life.

"FIGURES CAN LIE"

Margaret Knight, "Figures Can Lie,"
Science Digest, 30(3):52-53, September 1951.
As condensed by *Science Digest* from *The Listener*, London

When a statistician says that there is a correlation between two things, what he means is simply that the two things tend to go together, or to vary together. For example, there is a correlation between the age of children and their height. If you take a hundred children and arrange them in order of age, and then arrange them again in order of height, you will find that the two orders are not so very different. Again, there is a correlation between the intelligence of children and their progress in school; between income and the amount spent on food—and so on.

When two things are correlated in this way, it often is the case that the variations in one directly cause the variations in the other. For example, if, in an agricultural research station, there was found to be a correlation between the amount of cod-liver oil given to young pigs and the rate at which they grow, then—if other conditions had been kept the same—it would be a pretty safe assumption that it was the extra cod-liver oil that had caused some of the pigs to grow faster than others.

But not every correlation implies a direct causal relation of this type. Here is an example: In any large school, one would certainly find a correlation between the size of the pupils' feet and the speed of their handwriting.

This is a typical case where two things are related through a common third factor, and the third factor in this case is obviously age. It is the oldest children who have the biggest feet, and the oldest children who are the quickest writers.

That sort of mistake, in a less obvious form, is very easy to make. For example, it was shown some time ago that there is a correlation between the intelligence of children and the age of their fathers when the children were born. In other words, middle-aged and elderly men tend

to produce children who are more intelligent than the children of younger men.

It looked at first sight as though some new, and very unexpected, biological principle had been found.

But here again we are not dealing with a direct cause-and-effect relationship. This odd fact, that older fathers tend to have more intelligent children, depends for its explanation on three other facts. These facts are, first, that intelligence is strongly hereditary; secondly, that the most intelligent class in the community, by and large, is the professional class; and thirdly, that (by and large again) it is the professional class who are least given to early marriages.

Later marriages mean older fathers, so the fact that older fathers tend to have more intelligent children is just a by-product, so to speak, of the fact that older fathers are more often members of the professions.

The same sort of mistake is liable to be made with many other types of statistical data. The death-rate from cancer provides a good example. Statisticians tell us that for many years the death-rate from cancer has been slowly but steadily rising: and not unnaturally, many people conclude from this that for some reason or other we are becoming more susceptible to cancer.

Actually, that conclusion does not follow at all. The rise in the cancer death-rate is probably due entirely to the fact that other causes of death have been reduced. Numbers of people who, if they had been born a century earlier, would have died in their twenties of typhoid or smallpox, say, are now living on into their seventies and dying of cancer.

In a Dublin hospital, many years ago, it was noticed that the death-rate was markedly higher in the ground-floor wards than it was in the wards upstairs. This fact was commented on in an official report, and marked down as requiring investigation. Then it was discovered that, when new patients came in, the porter of the hospital was in the habit of putting them upstairs if they could walk by themselves, and downstairs if they could not.

Chapter 7—Directing the Paper to the Reader

Reprinted from *Gods, Graves, and Scholars*
by C. W. Ceram, translated from the German by E. B. Garside,
pp. 177-84, by permission of Alfred A. Knopf, Inc.

Carnarvon and Carter looked down upon the Valley of the Kings. Dozens of others had dug there before them, but not one of these many predecessors had left behind any exact drawings or even rough plans for the guidance of future explorers. Great heaps of rubble towered on all sides, giving the valley floor a lunar aspect. Among the heaps, like pit-heads, were the entrances to already exploited tombs. The only possible mode of attack was to dig systematically down to the rocky floor. Carter proposed to excavate in a triangular area bounded by the tombs of Ramses II, Merneptah, and Ramses VI. "At the risk of being accused of *post actum* prescience," he says, "I will state that we had definite hopes of finding the tomb of one particular king, and that king Tut.ank.-Amen." . . .

Once Carnarvon and Carter had begun the actual digging, in one winter's work they cleared away from within their triangular area of operation a large part of the upper layers of piled rubble and reached the foot of the tomb of Ramses VI. "Here we came on a series of workmen's huts, built over masses of flint boulders, the latter usually indicating in The Valley the near proximity of a tomb."

What now unfolded was extremely exciting, viewed within the context of the whole Tutankhamen drama. Since further attempts to enlarge the excavation in the projected direction would have blocked off the entrance to the tomb of Ramses, a very popular site with tourists, work was stopped until the work could proceed unhampered. Excavation was resumed in the winter of 1919-20, and at the entrance to the tomb of Ramses VI a small, but archaeologically important deposit of funerary materials was unearthed. "This was the nearest approach to a real find that we had yet made in The Valley," Carter remarks. . . .

On November 3, 1922—Lord Carnarvon was away in England at the time—Carter began to tear down the workmen's huts. The next morning a stone step cut into the rock was discovered beneath the first hut. By the afternoon of November 5 enough rubbish had been cleared away to

establish beyond doubt the fact that the entrance to the tomb had indeed been found.

But it might very well have been an unfinished tomb, one that, perhaps, had never been used. And if the tomb did contain a mummy, it might, like so many others, have already been plundered. And perhaps, to complete the list of pessimistic possibilities, the mummy was there, but might be nothing but that of some high official or of a priest.

The work was pressed feverishly, Carter's excitement mounting as the day wore on. Step after step appeared out of the rubble, and as the sudden Egyptian night closed in, the level of the twelfth step came to light, disclosing "The upper part of a doorway, blocked, plastered, and sealed. A sealed doorway—it was actually true, then! . . . It was a thrilling moment for an excavator."

Carter examined the seal and found it to be that of the royal necropolis. A royal seal was clear proof that a person of very high standing was interred within. Since the workmen's huts had lain directly above the opening, it was obvious that at least since the Twentieth Dynasty the tomb had never been plundered. And when Carter, shaking with agitation, bored a peephole in the door "just large enough to insert an electric torch," he discovered that the corridor behind the door was filled to the brim with stones and rubble—further reassurance that elaborate protective measures had been taken with the tomb.

On the morning of November 6 Carter sent the following telegram to Lord Carnarvon: "At last have made wonderful discovery in valley; a magnificent tomb with seals intact; re-covered same for your arrival; congratulations." On November 8 two replies from Carnarvon were received: "Possibly come soon"; and "Propose arrive Alexandria 20th."

On November 23 Lord Carnarvon, accompanied by his daughter, arrived in Luxor. For more than two weeks Carter had been waiting, consumed by impatience, on guard at the carefully covered tomb entrance. Two days after the discovery of the steps he had been flooded with messages of congratulation. But congratulations for exactly what? What was in the tomb? At this time Carter could not have said. Had he dug only a few inches lower down, he would have come upon the unmistakable seal of Tutankhamen himself. "Had I but known . . . I would have cleared on," says Carter, "and had a much better night's rest in consequence, and saved myself nearly three weeks of uncertainty."

On the afternoon of November 24 the workers shoveled the last of the flight of steps free of rubbish. Carter went down the sixteen steps and stood before the sealed door. Now he could get a clear impression of the seal of Tutankhamen. And now, too, he became aware—the Egyptologist's typical experience—that others had been there before him. Here, too, robbers had done their work.

"Now that the whole door was exposed to light," Carter says, "it was possible to discern a fact that had hitherto escaped notice—that there

had been two successive openings and re-closings of a part of its surface: furthermore, that the sealing originally discovered, the jackal and nine captives (the necropolis seal), had been applied to the reclosed portions, whereas the sealings of Tut.ankh.Amen covered the untouched part of the doorway, and were therefore those with which the tomb had been originally secured. The tomb then was not absolutely intact, as we had hoped. Plunderers had entered it, and entered it more than once—from the evidence of the huts above, plunderers of a date not later than the reign of Rameses IV—but that they had not rifled it completely was evident from the fact that it had been re-sealed."

But more revelations were in store for Carter. His confusion and uncertainty increased. When he had had the last of the rubbish blocking the stairs shoveled away, he found potsherds and boxes, the latter with the names of Ikhnaton, Sakeres, and Tutankhamen on them, also a scarab belonging to Thotmes III, and a piece of another, this one with the name of Amenophis III inscribed on it. Could all these names mean, against all expectation, a jointly shared rather than a single tomb?

Certainty could be achieved only by opening the door of the tomb. The next days were spent preparing for this move. Carter had seen the first time he looked through the peephole that the interior passage was clogged with rubble. This filling consisted of two clearly distinguishable kinds of stone. The shoulder-wide entrance cut by the robbers had itself been replugged with a kind of dark flint.

After several days of hard work the excavators, having penetrated thirty-two feet into the passage, found themselves hard up against a second door. The impressions of the royal seal of Tutankhamen and of the necropolis seal were also on this door, but there were signs, too, that intruders must have broken past this second obstruction.

Basing their reasoning on the resemblance of the whole layout to a cache of Ikhnaton that had been found near by, at this state Carnarvon and Carter, with good reason, were tempted to believe that they were dealing with a common tomb, and not the original grave of an Egyptian king. And was there much to expect in a cache, especially one that had already been visited by robbers?

Their hopes, in short, for a time were dashed. The tension increased once more, however, when rubble was taken away from the second door. "The decisive moment had arrived," Carter says. "With trembling hands I made a tiny breach in the upper left hand corner."

Taking an iron testing-rod, Carter poked it through the door and found an emptiness on the other side. He lit candles to ensure against poisonous gases. Then the hole was enlarged.

Everyone interested in the project now crowded about. Lord Carnarvon, his daughter, Lady Evelyn, and Callender, the Egyptologist, who had rushed to offer his help upon first receiving news of the find—all looked on. Nervously Carter lit a match, touched it to the candle, and

held it toward the hole. As his head neared the opening—he was literally trembling with expectation and curiosity—the warm air escaping from the chamber beyond the door made the candle flare up. For a moment Carter, his eye fixed to the hole and the candle burning within, could make out nothing. Then, as his eyes became gradually accustomed to the flickering light, he distinguished shapes, then their shadows, then the first colors. Not a sound escaped his lips; he had been stricken dumb. The others waited for what seemed to them like an eternity. Finally Carnarvon could no longer contain his impatience. "Can you see anything?" he inquired.

Carter, slowly turning his head, said shakily: "Yes, wonderful things."

OUT OF THE NIGHT

H. J. Muller, *Out of the Night*,
New York, The Vanguard Press, Inc., 1935, pp. 24-28

Now this peculiar creature, man, has as yet had only a very short probationary period. Recent findings in radioactive rocks have given testimony that the entire process of organic evolution on the earth has taken something like a thousand million years, at least—possibly even several times as long. Only by comparisons can we grasp such immensities, so let us imagine this period symbolized by a distance along a cord, each yard of which stands for 10,000 years, and which ends, in the present time, at some established point of reference—say the center of the private desk of J. P. Morgan in his office in Wall Street, New York City. To represent the beginning of organic evolution we should have to start the string many miles away—probably at least as far off as New Haven, possibly as far as Boston.

It is of interest to note that, on this scale, a human generation (from one birth to the next) would occupy somewhat less than an eighth of an inch, and that, if our symbolic cord were taken as about three-eighths of an inch wide (a small rope), the portion included within one generation would then be a disc-shaped cross-section having the approximate dimensions of an ordinary aspirin tablet. Now this is just equal to the volume of hereditary material which actually is contained in one generation of mankind, and which is to be passed on to the next generation. Hence our cord now acquires a further symbolic significance, in that it may be taken as representing in a certain real physical sense the evolving germ plasm of ourselves and our ancestors—though it would not everywhere be of equal width, as the numbers of the population change. Within this cord the fine fibers represent the chromosomes themselves, which are in fact filamentous bodies that intertwine, separate, and reunite in diverse

ways as they pass along from generation to generation in the varying combinations resulting from sexual reproduction. In this cord, then, there would be material which, from the beginning, has continued to make generation after generation of progressing forms. Their bodies (or soma), which constituted a vastly greater volume, may be considered as a series of excrescences about the cord, formed under the influences emanating from the by-products of the cord's chemical activity. The evolutionary changes manifested in their multitudinous characteristics are but reflections of primary changes occurring within the potent particles (genes) composing the tiny filaments of the cord itself. While the cord in question shows our particular line of ancestry, the lines of the millions of other living species would be shown by other, parallel cords—some thin, some thick, some branching as time goes on and as species diverge from one another, and many coming to an early end as species become extinct; but practically all the "higher" forms, at any rate, tracing back their origin to one original cord in the beginning. At any given place there is but a single one, out of all the mass of cords, which has led on so as finally to issue in our branch; this may be distinguished, in our figurative representation, by giving it a red color. It is this red cord which may be regarded as the red "thread of destiny," in a rather literal sense. Its free end is even now being spun further, being transfigured by mutation, being twined and interwoven, to give a new sort of living world, dependent on its new properties.

Let us now start at the beginning of the mass of life cords—say at New Haven—and follow along them on their long way towards their present destination in New York City, observing what forms are assumed by their bodily outgrowths (soma) as we travel forward. Except to the trained biologist, it will prove a dreary trip for much the greater part of the distance. For in this whole journey there will be no actual "beasts" as we ordinarily think of them (four-footed land animals) until we are well within the limits of New York City. Not until we are passing through Harlem shall we see any creatures with fur or feathers—i.e., mammals or birds. And note that even at that stage in our journey tremendous reptiles—dinosaurs—are still crashing over the earth; they long remain dominant over the few little warm-blooded pioneers, and they do not disappear until after we cross Forty-second Street. Not far below that point monkeys make their first appearance; but from that point southward the records show nothing higher than an ape until, having turned the corner of Wall Street, we actually confront our terminal building. There, about 100 feet from the end of the cord, are found the relics of the famous "missing link"—Pithecanthropus—not yet a man, but passed beyond the ape. Well within the building, and only about 15 feet from the desk in question, stands that stoop-shouldered lowbrow, the Neanderthal man, whom we do not dignify by classification in our species—the species self-styled *Homo sapiens*, "man the wise."

Our own *Homo sapiens* leaves his first known remains within the private office, only seven and a half feet from the desk. The earliest known "civilization" (not over 14,000 years ago, according to maximum estimates) leaves its crockery a yard and a half from the desk. On the desk, one foot from the center, stands old King Tut. Five and a half inches from the center we mark the Fall of Rome and the beginning of the Dark Ages. Only one and a half inches from the present end of the cord come the discovery of America and the promulgation of the Copernican theory—through which man opens his eyes for the first time to the vastness of the world in which he lives and to his own relative insignificance. Half an inch from the end of the cord there start the first faint reverberations of the Industrial Revolution, which set this desk here and which is now completely transforming man's mode of existence. A quarter of an inch from the end Darwin speaks, and man awakes to the transitory character of his shape and his institutions.

Chapter 8—Scientific Style

Alfred North Whitehead,
The Aims of Education and Other Essays,
New York, The Macmillan Company, 1929, pp. 19-20.
Used with permission of The Macmillan Company

Finally, there should grow the most austere of all mental qualities; I mean the sense for style. It is an aesthetic sense, based on admiration for the direct attainment of a foreseen end, simply and without waste. Style in art, style in literature, style in science, style in logic, style in practical execution have fundamentally the same aesthetic qualities, namely, attainment and restraint. The love of a subject in itself and for itself, where it is not the sleepy pleasure of pacing a mental quarter-deck, is the love of style as manifested in that study.

Here we are brought back to the position from which we started, the utility of education. Style, in its finest sense, is the last acquirement of the educated mind; it is also the most useful. It pervades the whole being. The administrator with a sense for style hates waste; the engineer with a sense for style economises his material; the artisan with a sense for style prefers good work. Style is the ultimate morality of mind.

But above style, and above knowledge, there is something, a vague shape like fate above the Greek gods. That something is Power. Style is the fashioning of power, the restraining of power. But, after all, the power of attainment of the desired end is fundamental. The first thing

is to get there. Do not bother about your style, but solve your problem, justify the ways of God to man, administer your province, or do whatever else is set before you.

Where, then, does style help? In this, with style the end is attained without side issues, without raising undesirable inflammations. With style you attain your end and nothing but your end. With style the effect of your activity is calculable, and foresight is the last gift of gods to men. With style your power is increased, for your mind is not distracted with irrelevances, and you are more likely to attain your object. Now style is the exclusive privilege of the expert. Whoever heard of the style of an amateur painter, of the style of an amateur poet? Style is always the product of specialist study, the peculiar contribution of specialism to culture.

Words Frequently Misspelled by Students of Science

abscissas	controlled	indispensable	precede
accelerator	co-ordinate	laboratory	preparation
accommodate	definite	lesion	primitive
accumulate	dental	lining	principal
affect	dentistry	liquefy	principle
alcohol	descend	longitudinal	proceed
align	description	maintenance	psychiatry
analysis	develop	manageable	psychology
archaeology	development	mathematics	pyramidal
arranged	diaphragm	necessary	quantity
auxiliary	differentiation	nickel	recurrence
benefited	dissection	ninety	relative
boundaries	distill	noticeable	rhythm
boundary	effect	nucleus	secretory
briefly	eighth	occasion	separate
caliber	environment	occurred	similar
cartilage	equipped	occurrence	stratified
category	exhaust	ophthalmology	supersede
cavities	existence	origin	surfaces
cavity	foreign	parallel	symmetry
circumference	forty	peripheral	temperature
committee	fundamental	periphery	vacuum
comparative	fusion	permanent	variety
consciousness	height	physiology	vein
continuous	homogeneous	practically	X-ray

LITERATURE BY SLIDE RULE

Stephen E. Fitzgerald, "Literature by Slide Rule,"
The Saturday Review, 36(7):15 ff., February 14, 1953

Anyone who writes for a living these days can hardly escape the readability boys and their word-counting machines. They remind us from every rostrum that our prose—especially our business prose—fails to

communicate. Something must be done to "clear away the roadblocks from our channels of mutual understanding." Only yesterday the readability movement was hardly more than an art; today it is an industry. Dozens of corporations retain readability experts to tell their executives how to write memoranda to each other; there is a spate of books on the capacity of words to get themselves understood; public relations counsellors who found themselves caught short a few years ago by the rise of so dramatic and salable a specialty are now equipped to discuss the problem learnedly with their clients. Readability—science, art, or industry—has arrived.

As one who must produce some form of business prose almost every day, I rise to protest: the movement has gone too far. No one familiar with the problem would deny that the readability proponents have a point; a lot of our workaday prose is dreadful. But is the alternative to bad writing a retreat to the style of a mail-order catalogue—clear but dull? Must our sentences always be short and staccato because we lack the skill or patience to write longer, better ones? Must we distribute punctuation marks in accordance with a formula, instead of according to rhythm and style? Must we always abandon the colorful, complex word in favor of a shorter, plainer one? Must we be mechanical in order to be clear?

I can already hear the shouts of anguish from some of my colleagues: I am overstating the case. But I venture to doubt it. For years I have believed in the principles of readability and, within reason, have tried to practise it. I have even been so rash as to write about it with some enthusiasm. And why not? Surely the virtues of clarity are obvious. No one argues with Elton Mayo's comment that "social study should begin with careful observation of what may be described as communication; that is, the capacity of groups to communicate effectively and intimately with each other." And yet, Mayo or no Mayo, I still think the readability boys are going too far. They threaten to put our words into a literary strait jacket, leaving us only the solace of an illusion—that, by shortening our sentences, we have somehow clarified our thought. Let me try to demonstrate.

One of our first lessons is to avoid the long sentence, to chop our thoughts up into less ponderous sections. This leads in practice if not in theory to an especially bumpy kind of short-winded prose, emphasizing unduly the importance of the period key on the typewriter. No first-rate writer has ever neglected the short sentence, and even the readability advocates are at some pains to point out that some interlarding of short and long sentences makes for variety. But one can hardly expect the tycoon to be also a stylist; and it is brevity as such—brevity as a formula—which has caught the businessman's imagination and encourages so Spartan a corporate style.

In their zeal for brevity of form—in the sentence, the clause, the word—the readability disciples are sometimes likely to forget that brevity

does not necessarily equate with clarity. In fact, one often encounters the implication that brevity does make for clarity. We are constantly reminded, for example, that important business executives like to have even the most complex and lengthy reports reduced to no more than one page for their use. This alleged attribute of executive skill has been laid to men so diverse as Winston Churchill, the late William Knudsen, and the late E. R. Stettinius, Jr. I happen to have known and worked with Knudsen and Stettinius, and I can report that both of them, like dozens of other industrialists I know, were quite capable of dealing with ideas which took more than one page to express. As for Mr. Churchill, his own prose is everywhere a vivid demonstration of disdain for brevity.

I would like to suggest the following twin thesis: a clear idea may be expressed in a rather long form; a thought capable of brief expression may yet be (a) unclear and (b) incorrect. As someone else has said, a short word can be as vague as a long one, and a short sentence more misleading than a book.

A close second to the insistence on brief sentences is the plea for colloquialism. Just "talk as you write." When we talk among ourselves, we are advised, we talk naturally and in short bursts. But when we write, especially if we are not writers, we tend to tighten up, to indulge in circumlocutions. So the solution is to "write naturally," informally, in a shirt-sleeves kind of prose.

This comes very close to the edge of nonsense. Talking and writing are quite different forms of communication, and the fact that both employ words is as irrelevant as the fact that brain surgeons and butchers both employ knives. The reason we communicate effectively while talking to one another is because we use a lot of tools besides words. We use our eyes and our hands and gestures to supplement the words; we veer and tack and change course in accordance with the immediate reactions of the audience; we inject footnotes and oral parentheses as we go along. These are a few of the reasons why the psychologists all agree that face-to-face speech is still the most effective single means of communication we have. But it is a total *non sequitur* to assume that the same words, shorn of their physical, face-to-face orientation, can communicate as well from the printed page.

I have had a good deal of personal and painful experience with the so-called advantages of colloquial, "natural" talk. An example which comes to mind is the vocal style of Mr. Knudsen, the production genius who headed the Office of Production Management during the early days of World War II, when I was an information officer for that agency. During his press conferences, which I had to attend as a matter of duty, Knudsen got his general ideas across very well. He was not a facile speaker, and he was often hampered by his accent. But the reporters who were there during the whole performance usually left with the idea that they had got his drift. Quite the opposite was the case with those

journalists who had to depend on the transcript. For Knudsen's transcripts were often unintelligible, largely made up of incoherent sentences without beginnings, middles, or ends. Heavy editing was essential. The travail involved formed in me an unquenchable conviction that to write as you talk is to ignore this major fact: an advantage of formal prose is that it permits us to write better than we talk.

We are also advised to take a dim view of foreign and complex words. We should prefer the Anglo-Saxon monosyllable. It is easy to be persuasive with this argument: one can always cite some example of Government "bafflegab"—"increasing disutility" for example. But when such advice is taken literally, and businessmen are often quite literal, it can lead to some absurd results. Labor and management negotiators should presumably forego such words as "negotiations" and report to their principals that they are engaged in "treating with one another with a view to coming to terms." A word like "bonus" is obviously out of order (though I suspect that most employes understand it), and the word "vacation" is similarly inept. If the corporate president gives a speech, let him not say anything about "patriotism": it would be better to say "love of country."

Again I can hear the wails: this is carrying things close to the point of absurdity. Well, I knew someone was being absurd, but I thought it was the readability boys with their counting machines. If we are to avoid long words, foreign words, and complex words, then I can only assume that we are to avoid them—and thus avoid some of the best known words in the language. Of course, says the readability man (a little testily), we should use some common sense. But does this mean that we must abandon the formulas and the word counts? Since we are advised to avoid words with prefixes, affixes, and suffixes, this means that we should avoid such words as "prefix," "affix," and "suffix." And it means as well that such common words as "postpone," "prearrange," and "improbable" should be eschewed (so, for that matter, should be the word "eschewed"), because they do not test out well on the counting machine.

I for one have no confidence in formulas that have to be modified at every turn by common sense: that is a negation of the meaning of the word formula. On the other hand, if common sense is to have the upper hand, then what is all this talk about formulas for? Salesmanship?

The readability men seem to forget that foreign and complex words—yes, even long words—can have qualities of zest and color and impact totally lacking in their plainer equivalents. Lincoln, for example, might have said: "Eighty-seven years ago, the people who were here before we were started a new country. They had two main ideas. One of these was the idea that it is good to be free. The other idea was that everybody ought to be thought of as being just as good as everybody else." This may or may not be clearer than Lincoln's original very conceptual language—clearer, perhaps, to a readability expert—but I doubt that we would have remembered it so well. Another example: a man who says "good clear

writing is better than unclear writing" does not appear to be saying much that has not already been said for a good many centuries; but a man who says "I am a readability expert" has got something he can sell.

Perhaps you think I exaggerate this preoccupation of the readability boys with numbers, formulas, and yardsticks. Well, hear this: while consulting one recent and well-known volume on the subject, I found that if I wanted to test my own prose I would have to obtain a straight-edge so that, after making a detailed count of such things as personal words and personal sentences, and words per sentence, and syllables per 100 words, I could then, with the straight-edge, connect four columns of "counting" figures with two columns of "scoring" figures, and thus discover both how "interesting" and how "easy" my prose was. My own judgment—and even that of my reader—does not have a place in the formula. In still another test, I am advised to make sure that my copy does not have too high a "fog index." How is "fog index" by way of a cloudy phrase? If I may be permitted a short comment, free of long words and with presumably a low fog index, I would like to say: all this strikes me as being very silly.

In their very vocal support for their counting machines, the readability scholars have been curiously silent about three communication facts which seem to me relevant.

1.) Why has some of the most efficient and communicative language in the world—in terms of its impact—been so complex according to the scales, while some of the simplest possible prose—in terms of its word counts and sentence lengths—fails so miserably? Any standard list of "most influential books" confronts the reader with an array of authors whose fog index was undeniably high, and whose readability scores are low, such men as Hobbes, Milton, Locke, Adam Smith, Malthus, J. S. Mill, Darwin, Freud, Veblen, Dewey, and all the rest of them. But they managed to communicate, and they continue to do so. Could it be because they had something to say? I think so. And I am afraid that as much cannot be said for some of the millions of propaganda pieces now being written in a kind of Pidgin English in an effort to entrap one more reader into more clearly comprehending an idea which is not necessarily either interesting or true to start with.

2.) Writing is essentially a two-way proposition. The existence of writers implies the existence of readers, and both readers and writers must make some effort. Mortimer Adler, for instance, has advised us that we must read a book three times, or at least from three different points of view, if we expect to extract its full content. It was Adler who also remarked that in the writing-reading relationship, as in baseball, catching the ball is just as important as hitting it. The readability advocates will retort that we should not ignore a reader simply because he has no reading skills; there are, after all, a great many unwilling readers whom "we" wish to reach. This seems to me irrelevant. There are a great many ways to communicate with people who cannot or will not read—

pictures, movies, meetings, comic books, perhaps even a little more pay in the old envelope. Simply because these problems exist we need not reduce all our daily prose to a see-the-man-what-is-the-man-doing level. Writing is not the only method of human communication. To insist on stripping it down to the lowest levels of understanding is as though we were to insist on reducing all music to the primitive rhythm of a jungle beat, thus hoping to widen our audience.

3.) At times one gets the impression (though this is not entirely so) that the readability boys have ignored the difference between words and ideas—that, in effect, they assume that words alone can do the job. All recent psychological experiments in communications indicate, if they do not prove, that people's receptivity to communications symbols and signals depends on a very wide variety of stimuli: the personal interest they may have in the fact or idea; their preconceptions about it; whether they think the thought is significant or noteworthy; whether it is presented with authority; whether it affects their immediate welfare. In short, the research would imply that it is usually more important to sharpen the ideas than to sharpen the words. The readability boys, of course, can retort that they cannot do everything: they must take the ideas as they find them and try to express them more simply. My counter retort is that this often does not help: reliance on four-letter words can lead to a quite false impression that something good has been accomplished when, in fact, no such attainment has been reached.

Let me repeat my belief in the basic *theory* of readability. These days all of us must write to some extent, and as the world grows more complex the number of people who must write in order to communicate grows larger. Anybody who knows how to improve that process gets my vote. What I am complaining about is that the readability concept, basically sound, has somehow got off the track. That deviation can perhaps be traced to the possibility that the disciples have studied at two fonts of wisdom and have misunderstood both of them. One of these sources of inspiration is that of Ogden and Richards, whose investigations led to what we now know as "Basic English." The other source was without much question the pioneer work of the late Count Korzybski, who was more than anyone else responsible for the theories of general semantics. It is a sad fact that neither Ogden and Richards nor Korzybski were primarily interested in what most people today believe they were.

Ogden and Richards, for example, never thought of Basic English as a substitute for everyday English. They were more interested in the possibility of inventing a new international tongue, more acceptable and more realistic than such novelties as Esperanto. They were more interested in the idea that, in English-speaking countries, Basic might become a great teaching aid for foreigners. This idea of Basic—with only sixteen verbs and about 850 words altogether, in which you can describe anything—arose from a rather philosophical investigation into the relationship between things and the words we must use to describe things.

Ogden and Richards were primarily interested in language forms, and in the possibility of inventing a simplified form of English for very special use. Basic was always intended as an auxiliary for ordinary literary English, not as a substitute. Richards, who has written widely on the subject, has been at great pains to make this point. Anyone who thinks that Ogden and Richards felt that Pidgin English is the answer to our problems should consult their monumental work "The Meaning of Meaning," which contains some of the toughest literary going on record.

The confusion over the work of Korzybski is even more general. The word "semantics" is tossed about these days in any learned barroom conversation as though it concerned only the ease with which language can be understood. But Korzybski, as anyone can see who troubles to read his works, was only incidentally interested in the simplicity of language. You can write in one-syllable words and still, according to Korzybski, be as opaque as ever. Korzybski gets into such areas as anthropology, biology, botany, conditioned reflexes, education, entomology, genetics, mathematics, logic, mathematical physics, neurology, ophthalmology, physics, physiology, and psychiatry. Korzybski was concerned not so much with the complexity of *individual* words but rather with the *interrelationship* between words and things they represent or seem to represent. Korzybski was not primarily concerned with whether a word was long or short, foreign or domestic, complex or simple: he was much more concerned with whether it had any meaning in the context in which it was used. The writers of annual reports could learn much from Korzybski. Does the writer say: "We made a great deal of progress during the year?" This might be clear to the readability boys. Short, simple. But Korzybski would ask: "What do you mean by 'We'? What do you mean by 'made'? What do you mean by 'progress'?"

In the great mainstream of people's efforts to communicate with one another there are dozens of currents and eddies. The mechanical tools represented by what we call readability techniques—useful as they are—represent and can represent only a very small part of the equipment we need. At the same time, the fact that these techniques are mechanical, and therefore capable of being readily grasped, tends to give them a popularity out of proportion to their net worth, just as their use will surely tend to create an often false sense of accomplishment. On this general subject, Lord Dunsany had something appropriate to say: "There is a great tendency nowadays to place technique above inspiration, and, if the notion spreads, we shall have the diamond cutters valuing their tools more highly than the diamonds, with the result that, as long as they cut them in accordance with the rules of the craft, they will cease to care whether they cut diamonds or glass, and then will cease to know."

This is a sentence of sixty-five words, complex in form, containing foreign words, long words. Anybody who does not understand, raise his hand.

Chapter 12—The Report, Continued

Report on Site for Plant No. 3 for Tampa Electric Company, Tampa, Florida, Stone & Webster Engineering Corporation

REPORT

ON

SITE FOR PLANT NO. 3

FOR

TAMPA ELECTRIC COMPANY

TAMPA, FLORIDA

Stone & Webster Engineering Corporation

October 11, 1951

Mr. F. J. Gannon,
President,
Tampa Electric Company,
P. O. Box 111,
Tampa 1, Florida.

Dear Sir:

In accordance with your authorization, we have made a survey of available sites for additional power generating facilities to supply the Tampa Electric Company system. Our study included consideration of future developments on present sites as a result of which we recommend that no part of the present Hookers Point site should be sold, if sale can be avoided. Should it prove necessary to give up any part of the present holdings, every effort should be made to retain sufficient land for the installation of a fifth generating unit on this site, and to receive water-borne coal in the future.

We recommend early acquisition of a site on the east shore of Hillsborough Bay, south of Delaney Creek, designated Site C. The area and location of the property recommended for purchase are described in detail in the following pages of this report.

For long range planning, a site adjacent to Port Tampa should be considered, but present indications are that the fourth generating plant on the system should be constructed at an inland site where ample water is available, at least for cooling tower make-up. This plant could be supplied with oil fuel delivered at the recommended site south of Delaney Creek, and pumped to the inland station.

For further details, we refer you to the following pages.

Yours very truly,

(signed)

W. F. Ryan,
Engineering Manager.

TABLE OF CONTENTS*

* The page numbers, table numbers, and plate numbers are reproduced here as they appeared in the original report and therefore do not correspond to those of this book.

PURPOSE

Growth of the demand for electric power on the Tampa Electric Company system indicates the need for additional generating facilities. Limitations on the sites now occupied by generating plant dictate the desirability of obtaining additional property for this purpose. While existing sites may take care of the load growth for a limited period, an additional site or additional sites will be required at an early date.

SYSTEM DEMAND

The combined noncoincident demand on the principal system load centers in January, 1951 was 157,000 kw. Estimates made by the engineers of Tampa Electric Company indicate a demand of 285,000 kw during the winter of 1955-56. Allowing for diversity and losses, these demands would require a net generating capacity of 148,000 kw and 268,000 kw, respectively. Table 1, attached, shows a breakdown of the existing demand by districts and the expected demand in 1955-56 for the same areas. No effort has been made to estimate demands beyond the winter of 1955-56 but, as indicated by Table 2, it is unlikely that the net generating capacity required in the winter of 1960-61 will be less than about 400,000 kw, and it might exceed 500,000 kw.

The breakdown of load by districts shows that the present load and the expected load growth are more pronounced east of the present generating stations and that, while future load growth will be considerable in the City of Tampa itself and in the area to the north and west, the greater demand is to the east. Plate I shows the 1950-51, 1955-56, and 1960-61 loads by areas with respect to the power stations.

PRESENT CAPABILITY

The present net generating capability of the system is 175,000 kw, of which 65,000 kw is installed at the Peter O. Knight Station on the west side of Seddon Channel, and 110,000 kw in the Hookers Point Station on the east side of Sparkman Channel. No material expansion of capacity would be economical at the Peter O. Knight Station. An additional unit is now being installed at the Hookers Point Station with an estimated net capability of about 46,000 kw. If Tampa Electric Company retains ownership of all land now owned at this site, two additional units of like capability could be installed, rais-

ing the net generating capability of the station to 248,000 kw, and the net generating capability of the system to 313,000 kw. This is a winter time capability, when the peak occurs, with all units available and in prime operating condition. With the largest unit out, the net generating capability would be approximately 267,000 kw.

While the feasible developments at Hookers Point will provide sufficient capacity for the expected load in the winter of 1955-56, provided no substantial part of the land now owned is sold, adequate provision for subsequent growth requires installation of facilities on another site.

HOOKERS POINT SITE

The present Hookers Point plant contains three 30,000 kw generating units. The fourth unit, now being installed, has a name plate rating of 40,000 kw. The land now owned by Tampa Electric Company, shown on Plate II, is adequate for the future installation of two additional 40,000 kw units which would provide an ultimate plant with six units having a total name plate rating of 210,000-231,000 kw and a net capability of 248,000 kw.

In the past, a part of this site, including the south half of the slip, has been leased for shipbuilding operations. It is understood that the United States Navy wishes to acquire this part of the site by outright purchase. The rapidly growing load on the Tampa Electric Company system indicates that no part of this site should be sold, unless government pressure or demonstrated need for the property for national defense makes the sale advisable as a matter of policy. If it becomes necessary in the future to utilize coal received by water, the coal should be unloaded from the south side of the slip. While equipment could be installed to unload at the harbor line and convey the coal to storage in the rear of the station, such equipment would be awkward, unsightly, and expensive, and would create a cleanliness problem throughout the plant. Coal dust would be particularly objectionable with so much equipment installed out of doors on the harbor side of the plant.

Should it become necessary to dispose of part of the land, then every effort should be made to retain the entire harbor frontage, and also at least 320 ft of slip frontage, to permit the installation of six units and reasonable facilities for future delivery of coal by water, if the use of coal should ever become economical. An easement must be retained to permit discharge of circulating water to the slip.

Plate II shows what is considered the minimum area which should be retained, if it becomes necessary to sell any part of the present site.

AVAILABLE NEW SITES

Three sites were examined on Tampa Bay, designated as Site A, Site B and Site C on Plate III, attached. A survey of the entire waterfront indicated no other areas of much promise, but consideration has been given to an inland site which may be developed at some future time. Such an inland site would be located strategically with respect to water supply and load center, but no particular place is suggested at this time. For purposes of discussion, however, the inland site is designated as Site D.

SITE A

There is an adequate area of land which the U. S. Phosphoric Company is willing to sell on the south bank of the mouth of the Alafia River. The land is low and swampy, there is no present railroad access; a railroad siding would require bridging the Alafia River. Highway access, at present, is poor and the site is remote from the deep ship channel. The existing channel, originally 17 ft deep, would require extensive dredging to permit access by ocean going tankers. Circulating water may be contaminated by the adjacent chemical plant. This site has so little to commend it that it is given no further consideration in this report.

SITE B

A site could be developed adjacent to the ship channel at Point Tampa if authorization could be obtained to fill land south of the peninsula on which Port Tampa is located and embracing a small island, which at present appears to be unoccupied. This site would have the advantage of location on deep water for circulating water purposes and for fuel oil deliveries. Fuel oil, moreover, might be obtained from a supplier who would supply storage in a tank farm at the Port receiving a supply at the ship channel, and making deliveries as required to service tanks on the power station site. This site is not favorable with respect to the load under present conditions, since practically all of the capacity generated there would have to be transmitted to the north and east. For future load growth, a development at this site might conceivably take care of the load within the city and to the north and west of the present generating stations; the total demand in these areas may exceed 150,000 kw by the

winter of 1960-61. In view of the necessity of making land at this point, the possible delay in obtaining authorization for the same, and the distribution of the load, this site is not regarded as desirable for immediate use, but only as a long range possibility.

SITE C

Site C is a peninsula of filled land on the east side of Hillsborough Bay, an arm of Tampa Bay, immediately south of Delaney Creek. This site has the advantages of adequate area, reasonable proximity to deep water for circulating water purposes and for delivery of fuel, relatively high ground level, reasonable subsoil conditions, and strategic location with respect to future load growth and existing transmission systems. This site would also provide an excellent receiving point for oil fuel, if an inland site should be developed later. In view of all these factors, this area is considered the most desirable site for a power generating plant in the Tampa area.

Description

Site C consists of the northerly halves of sections 4 and 5, and a portion of the northerly half of section 6, Township 30-S, Range 19E. The location and extent of the property are shown on Plate IV. Highway access to the site is by way of Highway US 541 which abuts the property on the east. The distance by road from the City of Tampa is approximately 5 miles. Railroad connections to the site may be made with the Atlantic Coast Line Railroad, which runs southward from Tampa and is located 1/4 mile east of the property, or with the Seaboard Airline Railroad which runs eastward from Tampa and is located about 3 1/2 miles north of the property.

An existing ship approach channel about 220 ft wide, which was originally dredged in 1929 to a depth of 27 ft below mean low tide, extends about 3,500 ft from the main Government ship channel to a bulkhead at the outer end of a point of land on the property. No recent soundings have been made in this channel, but redredging would probably be necessary to restore the original depth. By additional dredging to 32 ft below mean low water, an approach channel as deep as the main ship channel could be provided.

The bulkhead was constructed in 1929 of steel sheet piling and hydraulic fill. Study of the design shown on the drawings from which the bulkhead was presumably constructed indicates that the original design contemplated a water depth of 27 ft below mean low tide. The design is not considered adequate for greater water depths at the bulkhead. At the present time, the steel sheeting is cor-

roded above the mean water level to such an extent that this portion of the bulkhead has no appreciable remaining strength and would require replacement with some form of new construction. The condition of the portion of the bulkhead below mean water level, which includes the sheet piling below this level, and the tie-back and anchor system will require complete inspection of its condition and investigation of its remaining strength before being used for its intended purpose. Pending results of the complete inspection, the existing construction must be considered as having doubtful value.

The hydraulic fill in the point of land extending from shore to the dock has been subjected to considerable erosion since it was placed in 1929. A large area, adequate for the initial power station facilities, on the outer end of the point is approximately 9 ft above mean low water, but a section of the causeway connecting this area to the shore is only a few feet above mean low water and would require filling for road and rail access.

The mainland portion of the site rises from less than 2 ft above mean low water at the shore line to about 5 ft above mean water level along Highway US 541. The higher portions of the site are covered with vegetation consisting principally of palmetto, with a few palm and pine trees. The lower portions are sandy areas with mangrove swamps and are submerged to a depth of approximately 1 ft at high tides.

The total area of the site within the property lines is 717.38 acres. Of this amount, approximately 260 acres are natural ground above high tide between the shore line and Highway US 541, less than 94 acres are above mean low water on the point, and more than 363 acres between the Government channel and the shore line are below mean low water.

Foundation Conditions

To determine the depth to rock and the character of the soils underlying the site, 24 soil borings were made to Stone & Webster Engineering Corporation specifications by Raymond Concrete Pile Company. All borings were driven to rock and alternate borings were cored at least 10 ft into rock to determine the continuity of the rock formation. Location of the borings and the classification of the materials by the driller and also by Stone & Webster Soils Laboratory are shown on Plates V and VI.

The depth to the rock surface varies from about 22 ft to about 35 ft below mean low water over all of the site except the 1,500 ft at the outer end of the point where the depth to rock surface increases rapidly to about 55 ft below mean low water. The soil underlying the site

consists principally of sand, silt and clay strata of varying firmness.

Foundations for all heavy or important structures would require the use of piles to rock. For lighter and unimportant structures located in the area between the shore line and Highway US 541 which would not be damaged by some settlement, soil bearing foundations could be used.

Development of Site for Power Generation

The arrangement of facilities for generation of power has been studied on the basis of installing one 60,000-66,000 kw unit initially, as shown on Plate IV, and the subsequent addition of five similar units providing a name plate capacity of 360,000-396,000 kw. The future capacity, however, is not limited to this figure by the physical characteristics of the site, but will be determined by future load demands.

Suggested boundaries of the land considered desirable for the power plant have been shown on Plate IV. These include approximately 128 acres, partially submerged, east of the existing bulkhead and 93 acres submerged between the bulkhead and the main ship channel.

The existing point of land has been selected as most suitable for the location of power generating facilities because of its proximity to deep water for fuel deliveries and condensing water supply. The existing land area of the point would provide sufficient space for initial development of the power plant at a minimum expenditure for land development. Strengthening the major portion of length of the existing bulkhead would be required for the initial development. Some erosion of the shore has taken place since 1929 when the point was filled. However, it is believed that no substantial investment in shore protection would be required for the initial power station development although some occasional expense for maintenance should be expected. For the future development, additional fill and some shore protection would be required. A proposed arrangement for the initial development and its relationship to the existing land area is shown on Plate IV.

The location of the power house on the point was determined by foundation conditions revealed by the test borings. Shorter piles could be used at this location with consequent lower foundation costs than at any point nearer to the present bulkhead. The lower foundation cost and shorter transmission lines would more than offset the extra cost of the longer condensing water supply piping required.

The circulating water intakes are shown located in

the reentrant corner formed by the existing sheet pile bulkhead in order to permit inflow of cooler condensing water from the deeper channel level and also to provide protection from shipping. It is contemplated that the intake pipes from the screen well to the power station could be aboveground most of the way. The condensing water discharge could flow from pipes into an open ditch or flume discharging into the bay until such time as future construction on the adjacent property might require extending the discharge to the west end of the point.

Space between the end of the point and the power station would provide for future coal storage and the fuel oil tanks could be located initially in this space. In the event of future conversion to coal, the oil tanks could be relocated east of the power station. Provision could be made to unload either oil or coal from ships at the end of the bulkhead initially as shown on Plate IV, or from a position at a slip to be constructed at a later date.

A 400 ft wide strip of land for transmission lines has been indicated along the north property line to permit transporting power away from the site. This location would be advantageous for the transmission lines and would also provide maximum use of the remaining portion of the site for industrial facilities. A 400 ft wide right-of-way for transmission lines extending south has been indicated adjacent to Highway US 541.

SITE D

If no waterfront site were available, it would be feasible to build an inland station to which fuel oil would be delivered by pipe line from a receiving and storage station on Tampa Bay. As previously stated, Site C would make an excellent location for such an operation. Under present conditions, the probable cost of power generation for Site D, including capital cost and operating expense, would be about the same as for a site on salt water. Since there are many suitable inland sites available, no action is necessary at this time, but the economics of this possibility make it possible to provide for future demands of any foreseeable magnitude.

For a future plant containing six 60,000-66,000 kw turbine generators, the comparative costs for an inland site and a deep water site are summarized as follows:

Additional First Cost and Power Cost of Inland Station over Tampa Bay Station

(Basis of Six 60,000 Kw Units)

First Costs		
Additional first cost fuel oil system	$2,500,000	
Additional first cost cooling tower system	3,300,000	
Credit for circulating water intake structures	2,000,000	
Credit for electrical transmission line	4,500,000	
Net credit first cost of inland station		$700,000
Capacity Charges		
Additional capacity charge for auxiliaries at $150 per kw	900,000	
Credit for capacity charge for transmission line at $150 per kw	1,200,000	
Net capacity credit		300,000
Net capital credit		1,000,000
Power Costs		
Additional power required by auxiliaries by inland station at $.004 per kwhr	190,000	
Credit for power loss in transmission line	45,000	
Net annual power cost	$145,000	
Net annual power cost capitalized at 15%		965,000
Total capital difference in favor of inland plant		$35,000

While one or more units might be operated at some inland sites without a cooling tower, it is considered conservative to assume a limited supply of cooling water for this preliminary comparison. Considering the inadequate data for the estimates, the indicated advantage of $35,000 for an inland plant, on a total plant cost in excess of $50,000,000, is of no significance. More detailed estimates would be required to determine whether there is any decisive advantage for either location.

CONCLUSIONS

The most suitable site for immediate acquisition is Site C, south of Delaney Creek. Early acquisition of this site is recommended, particularly if there is any doubt about retaining all of the land now owned at Hookers Point. More detailed studies and estimates might reveal a slight advantage for an inland site but, in view of the fact that there are many inland sites available, and only one or two on the waterfront, it is recommended that the Site C should be secured now, as none may be available later.

Assuming a future net demand in excess of 700,000 kw, which may be experienced in 12 to 15 years, the load may be carried by generating capacity of 65,000 kw net capability at Peter O. Knight Station, 248,000 kw at Hookers Point Station, 350,000 kw (net capability with largest unit out) at a new station at Site C, with the excess being carried at an inland station, on a site to be selected later. As a matter of convenience in construction and operation of the transmission and distribution systems, the inland generating plant may be desirable some years before Site C is fully developed and the latter might be started before a sixth unit is installed at Hookers Point.

It is understood that a sufficient area with right-of-way for transmission lines may be secured from the present owners of Site C, but that the owners do not wish to dispose of the entire tract for power generation and have requested a study of the possible development of their holdings for the use of other industries. This possibility has been covered in a separate report. Such a project is found to be feasible, and might result in attracting important power customers to the Tampa area.

Retention of the entire site at Hookers Point is strongly recommended. Should it be necessary to sell any part of it, every effort should be made to retain sufficient waterfront to provide for the installation of at least one unit in addition to the one now under construction, and to permit the future handling of water-borne coal.

LOAD FORECASTS*

TAMPA ELECTRIC COMPANY

DISTRIBUTION AREAS	Present Kva Capacity	Jan. 1951 Demand, Kw	Winter 1955-56 Estimated Demand, Kw
1 - Northwest			
Granville	2,000	2,224	6,000
Turner's Dairy	45	25	Est. 50
Lake Fern	300	320	900
Pinellas Water Co.	600	513	800
Oldsmar Race Track	150	96	200
Oldsmar	300	208	600
McFarland	1,000	688	1,600
Florida	1,000	880	2,000
	5,395	4,954	12,150
2 - West Central			
Hyde Park	3,750	4,016	7,500
Laurel	3,000	2,416	4,000
Plant Field	1,500	1,832	2,500
Gray Street	3,000	400	3,000
Drew Field	750	744	2,500
Ivy	3,000	1,216	3,000
Habana	2,500	2,256	5,000
	17,500	12,880	27,500
3 - Interbay			
Matanzas	3,750	4,496	7,500
Lois	3,750	3,888	7,500
West Shore	300	200	2,500
Port Tampa	1,000	520	1,200
MacDill	C.O.	2,058	4,000
Wyoming	1,500	1,136	3,000
Bay Court	3,000	4,512	7,500
	13,300	16,810	33,200

*By Engineering Department of Tampa Electric Company.

	Present Kva Capacity	Jan. 1951 Demand, Kw	Winter 1955-56 Estimated Demand, Kw
4 - Tampa City East of River			
Plymouth	5,500	4,832	9,000
Fern	6,500	6,704	10,000
14th Street	5,250	4,176	7,500
2nd Avenue	6,000	6,160	10,000
Polk	9,000	6,592	9,000
Washington	7,500	4,688	12,500
Florida Portland Cement	3,500	3,120	3,500
American Can	2,200	1,392	2,500
Gulf Florida Terminal	450	312	400
Davis Islands	1,500	1,408	2,500
McCloskey	1,500	536	2,000
Tampa Shipbuilding	C.O.	17	1,000
Curtis & Nebraska (1951)			
	48,900	39,937	69,900
5 - East Central			
Yukon	3,000	2,288	3,500
Temple Terrace	450	528	1,500
Temple Terrace Junction	100	56	200
Thonotosassa	600	252	600
Water Works	450	160	600
Belmont Heights	3,750	3,008	3,600
Diana (1951)			
49th Street	2,000	1,216	2,500
Lykes Packing	1,100	554	600
Causeway Boulevard	1,000	608	2,000
Alafia River	1,000	880	2,400
Uceta	600	395	500
Orient Park	1,000	1,120	1,700
Herman	600	256	300
U. S. Phosphoric	3,750	3,829	4,000
	19,400	15,150	24,000
6 - Plant City Division			
Seffner	3,000	1,132	1,500
Kingsgrove	1,450	492	1,000
Kingsway	450	488	1,000
Plant City	3,600	3,960	6,000
West Plant City (1951)		-	1,500
Hampton - 8 Kv	1,000	744	1,200
Sydney	C.O.	4,680	5,000
Hopewell	7,500	5,220	-
Keysville	600	288	500
	17,600	17,004	17,700

	Present Kva Capacity	Jan. 1951 Demand, Kw	Winter 1955-56 Estimated Demand, Kw
7 - Phosphate			
Nichols	8,500	7,680	10,000
Achan	4,500	3,000	3,000
Drymill	C.O.	3,096	3,000
Brewster	3,000	2,775	3,000
Saddle Creek	7,000	5,820	6,000
Oak Ridge Sand Pits	750	245	500
A. A. C.-Pierce	C.O.	-	15,000
Mulberry Town	2,000	816	2,000
Ridgewood	C.O.	5,670	3,000
New Pauway No. 4	C.O.	1,380	-
Pauway No. 4	C.O.	3,720	-
Clarke-James (New)	C.O.	-	8,000
Tenoroc	5,000	480	6,000
I. M. & C. (New)	C.O.	-	7,000
Armour	1,500	1,080	2,500
	32,250	35,762	69,000
8 - Winter Haven			
Eagle Lake	4,200	2,468	5,000
Winter Haven	3,000	3,744	6,000
Florence Villa	3,750	2,880	6,000
Auburndale	3,000	2,896	5,000
Adams	1,500	1,056	3,750
Lake Alfred	1,000	416	600
East Lake Alfred	1,500	224	500
Continental Can	1,500	48	1,500
Polk Packing	2,500	432	2,500
	21,950	14,164	30,850

Note: C.O. denotes Customer Owned.

NET GENERATING REQUIREMENTS

TAMPA ELECTRIC COMPANY

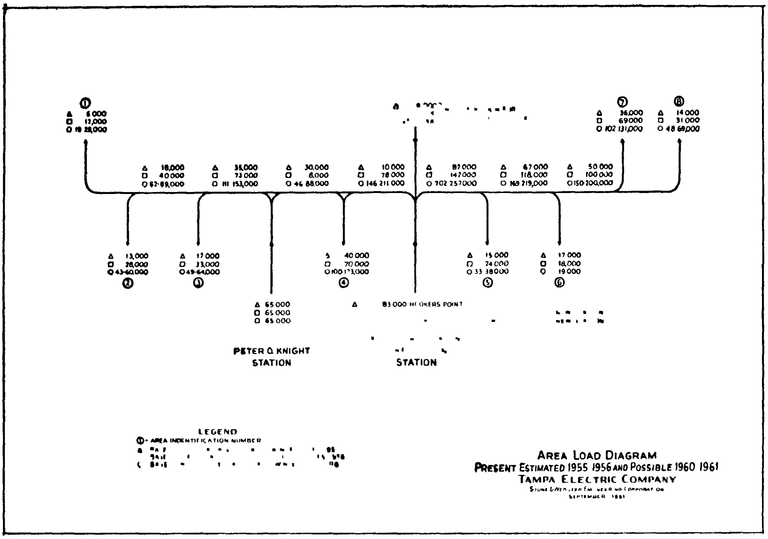
	Actual* Demand Winter 1950-51	Estimated* Demand Winter 1955-56	Possible Demand Winter 1960-61 (a)	Possible Demand Winter 1960-61 (b)
Demand at Load Centers, Kw				
West of Peter O. Knight Station	35,000	73,000	111,000	153,000
Inside City Limits, East of Hillsborough River	40,000	70,000	100,000	123,000
East of Hookers Point Station	82,000	142,000	202,000	246,000
	157,000	285,000	413,000	522,000
Allowance for Losses and Diversity	9,000	17,000	25,000	31,000
Required Capability	148,000	268,000	388,000	491,000
Present Net Generating Capability	175,000			
Net Generating Capability with:				
One Additional Unit at Hookers Point	-	221,000	221,000	221,000
Two Additional Units at Hookers Point	-	267,000	267,000	267,000
Three Additional Units at Hookers Point	-	313,000	313,000	313,000
Present Generating Capability, Largest Unit Out	138,000	-	-	-
Deficiency - Largest Unit Out				
No Additional Units	10,000	-	-	-
One Additional Unit	-	93,000	-	-
Two Additional Units	-	47,000	167,000	270,000
Three Additional Units	-	1,000	121,000	224,000

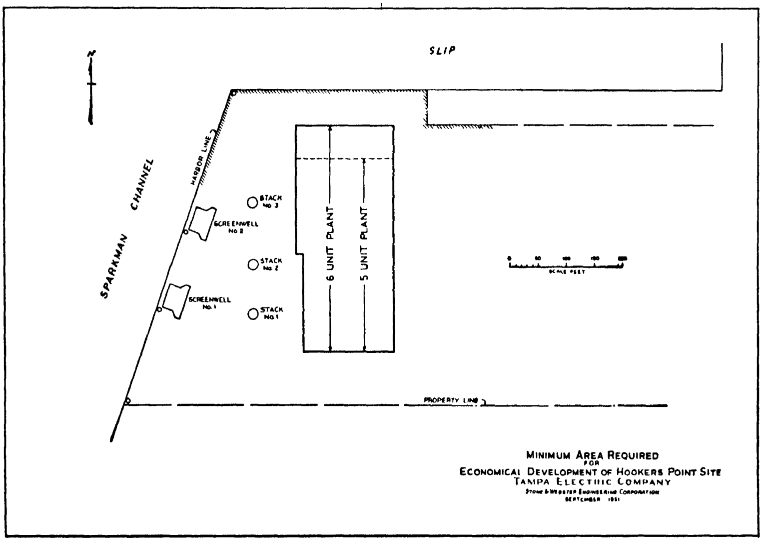
Specific future dates are used only for convenience. The figures listed for 1955-56 and 1960-61 should be interpreted to mean loads expected after the passage of 5 and 10 reasonably normal years, free from extraordinary government restrictions or business recessions.

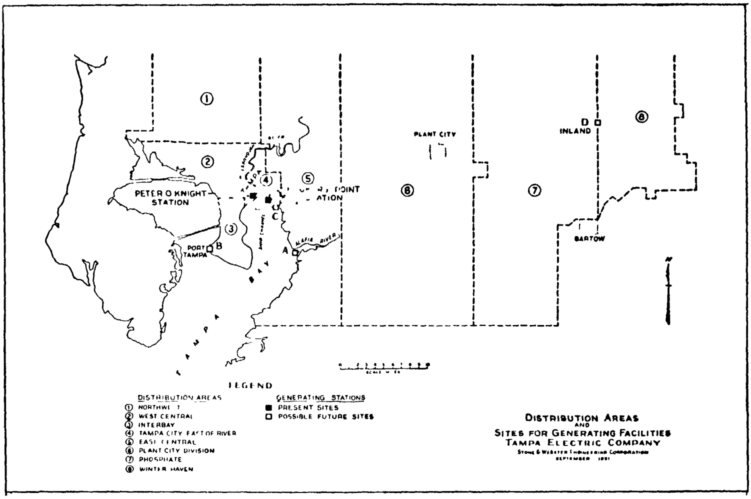
* Engineering Department - Tampa Electric Company

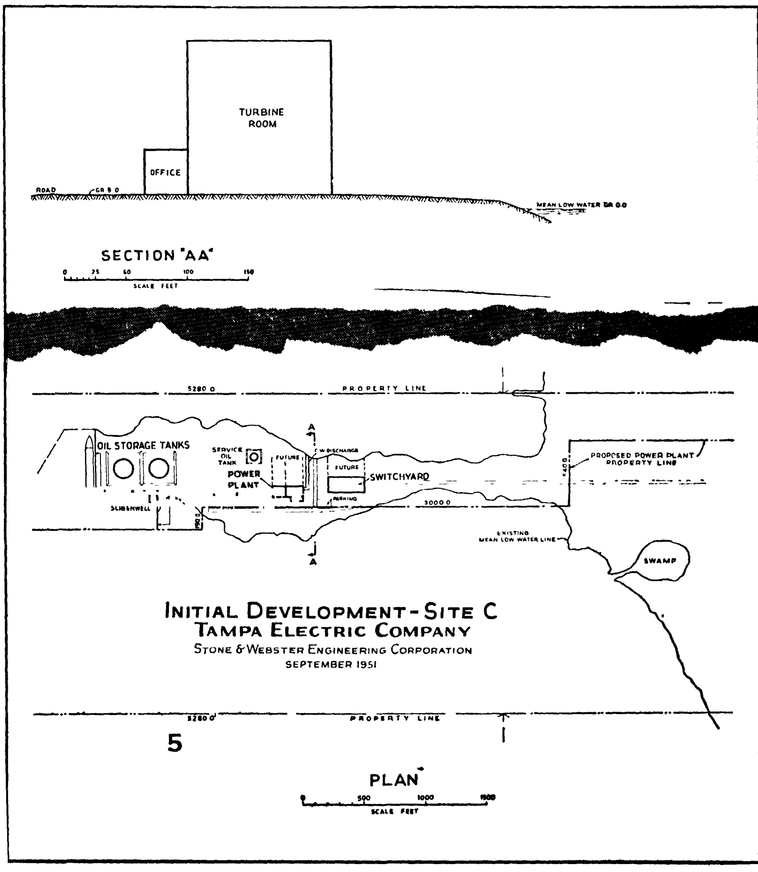
(a) Same total increase from 1955 to 1960 as from 1950 to 1955

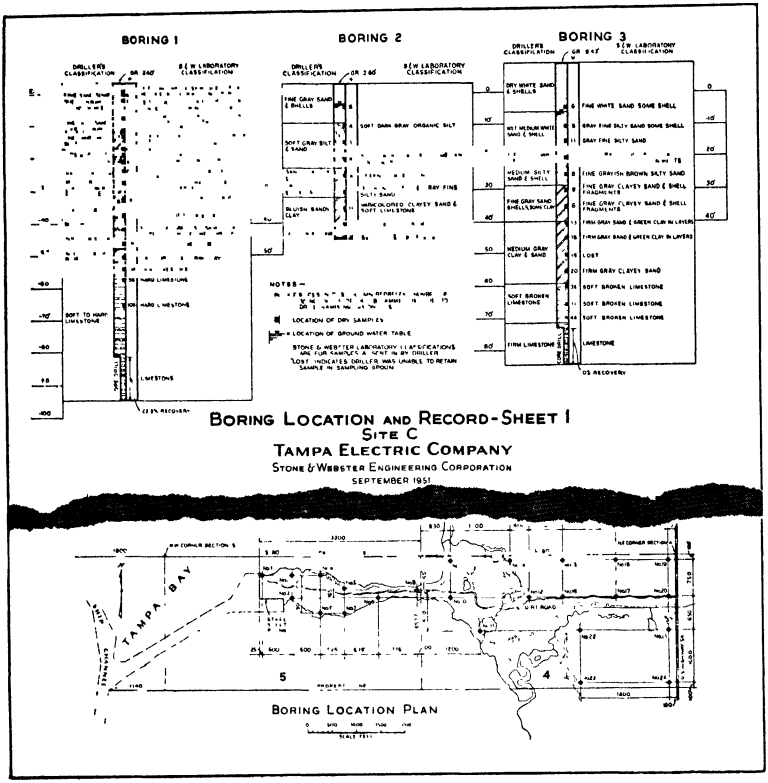
(b) Same percentage increase from 1955 to 1960 as from 1950 to 1955


PETER O. KNIGHT STATION
STATION
83 000 HOOKERS POINT
LEGEND
AREA INDENTIFICATION NUMBER
AREA LOAD DIAGRAM
PRESENT ESTIMATED 1955 1956 AND POSSIBLE 1960 1961
TAMPA ELECTRIC COMPANY
SEPTEMBER 1951


SLIP
HARBOR LINE
SPARKMAN CHANNEL
STACK No 3
SCREENWELL No 2
STACK No 2
SCREENWELL No 1
STACK No 1
6 UNIT PLANT
5 UNIT PLANT
SCALE FEET
PROPERTY LINE
MINIMUM AREA REQUIRED
FOR
ECONOMICAL DEVELOPMENT OF HOOKERS POINT SITE
TAMPA ELECTRIC COMPANY
STONE & WEBSTER ENGINEERING CORPORATION
SEPTEMBER 1951


PETER O KNIGHT STATION
PORT TAMPA
PLANT CITY
INLAND
BARTOW
ALAFIA RIVER
TAMPA BAY
LEGEND
DISTRIBUTION AREAS
(1) NORTHWEST
(2) WEST CENTRAL
(3) INTERBAY
(4) TAMPA CITY EAST OF RIVER
(5) EAST CENTRAL
(6) PLANT CITY DIVISION
(7) PHOSPHATE
(8) WINTER HAVEN
GENERATING STATIONS
PRESENT SITES
POSSIBLE FUTURE SITES
DISTRIBUTION AREAS
AND
SITES FOR GENERATING FACILITIES
TAMPA ELECTRIC COMPANY
STONE & WEBSTER ENGINEERING CORPORATION
SEPTEMBER 1951


TURBINE ROOM
OFFICE
ROAD
MEAN LOW WATER GR 0.0
SECTION "AA"
SCALE FEET
PROPERTY LINE
OIL STORAGE TANKS
SERVICE OIL TANK
POWER PLANT
FUTURE
SWITCHYARD
PARKING
SCREENWELL
PROPOSED POWER PLANT PROPERTY LINE
EXISTING MEAN LOW WATER LINE
SWAMP
INITIAL DEVELOPMENT - SITE C
TAMPA ELECTRIC COMPANY
STONE & WEBSTER ENGINEERING CORPORATION
SEPTEMBER 1951
5
PLAN
SCALE FEET


BORING 1
BORING 2
BORING 3
DRILLER'S CLASSIFICATION
S & W LABORATORY CLASSIFICATION
FINE GRAY SAND & SHELLS
SOFT DARK GRAY ORGANIC SILT
SOFT GRAY SILT & SAND
BLUISH SANDY CLAY
VARICOLORED CLAYEY SAND & SOFT LIMESTONE
HARD LIMESTONE
SOFT TO HARD LIMESTONE
LIMESTONE
DRY WHITE SAND & SHELLS
FINE WHITE SAND SOME SHELL
WET MEDIUM WHITE SAND & SHELL
GRAY FINE SILTY SAND SOME SHELL
GRAY FINE SILTY SAND
MEDIUM SILTY SAND & SHELL
FINE GRAYISH BROWN SILTY SAND
FINE GRAY CLAYEY SAND & SHELL FRAGMENTS
FINE GRAY SAND SHELLS SOME CLAY
FIRM GRAY SAND & GREEN CLAY IN LAYERS
MEDIUM GRAY CLAY & SAND
LOST
FIRM GRAY CLAYEY SAND
SOFT BROKEN LIMESTONE
FIRM LIMESTONE
NOTES —
LOCATION OF DRY SAMPLES
LOCATION OF GROUND WATER TABLE
STONE & WEBSTER LABORATORY CLASSIFICATIONS ARE FOR SAMPLES AS SENT IN BY DRILLER
"LOST" INDICATES DRILLER WAS UNABLE TO RETAIN SAMPLE IN SAMPLING SPOON
BORING LOCATION AND RECORD-SHEET 1
SITE C
TAMPA ELECTRIC COMPANY
STONE & WEBSTER ENGINEERING CORPORATION
SEPTEMBER 1951
TAMPA BAY
SHIP CHANNEL
DIRT ROAD
BORING LOCATION PLAN

APPENDIX B

BUSINESS LETTERS

The various forms of the report—the outline, memorandum, letter, short-form and long-form report—have been treated in Chapters 11 and 12. The more important types of letters used in industrial and scientific organizations and in educational and scientific institutions will be discussed and illustrated by examples in this appendix. These types are inquiries and replies, letters of application, informative and explanatory letters, and letters designed to further good public relations.

Good Business Letter Writing

Many people have the mistaken idea that business English is a highly specialized kind of English. Actually good business writing represents the effective application of the basic principles of composition to the transaction of business. Before beginning any business letter, the writer should consider the purpose of the letter and the person or persons to whom it is addressed, and then formulate a plan to achieve that purpose. Form letters, reproduced by a mimeographing or multilithing process, although usually impersonal in style, should not be permitted to become perfunctory or stereotyped.

The individual paragraphs are the building blocks of the business letter. The opening and closing paragraphs, as in other written compositions, are in the key positions. The first paragraph may either take up the essential business of the letter or establish pleasant relations with the reader before going on to that business. While the ending should round out the letter pleasantly, it should not be wasted on inconsequential matters. If some action or reply is desired from the reader, it should be stressed at the close of the letter. Intervening paragraphs present details, develop points, and offer subsidiary explanations. Except for very routine matters, such as making travel or hotel reservations, letters of less than two paragraphs are unusual.

The form of the business letter has become well established. Except for a few specialized types of letters, the following parts are standard: (1) the heading, which includes the letterhead or the sender's address and the date, (2) the inside address of the recipient, (3) the salutation, (4) the body of the letter, (5) the complimentary close, (6) the signature, which includes always the written signature and usually a typewritten signature beneath it, (7) the reference line, which gives the initials of the person dictating the letter followed by a colon or bar and those of the person typing it. When a letterhead is used, the date may be centered below it or placed at the right, whichever position gives the more balanced effect.

Since the letter represents the sender, appearance is important. The letter should be attractively framed on the page, with the side and bottom margins approximately equal. In a letter requiring more than one page, the second and later pages begin one to two inches from the top of the sheet, with the same side margins as on the first page. The second and later pages are, of course, numbered consecutively at the top, and the name of the addressee is often placed in the upper left-hand corner followed by the page number, as illustrated in the example on page 450. Most letters are single spaced with double spacing between paragraphs. The letter styles most favored for general, moderately conservative correspondence are the *block style,* in which all lines except the date, com-

plimentary close, and the signature are flush with the left margin, and the *modified block style,* which differs only in that the first line of each paragraph is indented.[1]

An important consideration in effective correspondence is *tone,* that is, the impact of the writer's underlying attitudes on the reader, the impression the reader receives from the letter. A letter may "sound" cordial, friendly, cold, peremptory, distant, or even captious or contentious. The practiced letter writer achieves a desirable tone by understanding the reader's point of view, by anticipating his reactions, and by choosing words and phrases wisely. Trite expressions, business jargon, unnecessarily negative phrases, misplaced slang or colloquialisms—all mar the tone of a letter because they convey the impression that the writer is indifferent to the reader or lacking in taste. While the language of a letter should not be stuffy or pretentious, letters dealing with matters of consequence should be dignified in tone. In general, however, the style of the business letter should be natural, simple, and direct.

Inquiries and Replies

A good letter of inquiry clearly, explicitly, and courteously requests the information desired. The letter on page 446 and the accompanying reply have the short paragraphs characteristic of business letters which deal with scattered details rather than with points requiring elaboration. It should be noted that the inquiry follows the *modified block style* with the date to the right, while the reply is the *block style* with the date centered.

A letter making a more technical inquiry would call for a correspondingly technical reply. The reply (see p. 448) to such an inquiry is an excellent example because of its pleasing opening, concise style, and effective handling of paragraph structure.

The example on page 449 was addressed to a correspondent who raised two questions in connection with a booklet, *The ABC's of Aluminum:*

1. If heat reflectivity has no relation to light reflectivity, as stated in the booklet, why does the condition of the surface of the aluminum affect its ability to reflect radiant heat?

2. Is the surface condition really important in the matter of reflecting radiant heat, or is the apparent decrease in the reflectivity of radiant heat which comes with weathered surfaces not really a decrease in the reflection of light waves, especially those near the red end of the visible spectrum?

[1] Among the references helpful in business letter writing are Robert R. Aurner, *Effective Communication in Business,* 3rd ed., Cincinnati, South-Western Publishing Company, 1950; A. Charles Babenroth and Charles Chandler Parkhurst, *Modern Business English,* 5th ed., New York, Prentice-Hall, Inc., 1955; L. E. Frailey and Edith L. Schnell, *Practical Business Writing,* New York, Prentice-Hall, Inc., 1952; Cecil B. Williams and John Ball, *Effective Business Writing,* 2nd ed., New York, The Ronald Press Company, 1953.

The friendly tone of the reply and the careful attention given to the inquiry are in marked contrast to the perfunctory replies which inquiries sometimes elicit.

The last example among the letters of inquiry and reply (see p. 451) shows an effective handling of a request which could not be complied with immediately. The writer of the reply has neatly avoided a negative opening, and the third and fourth paragraphs tend to leave the reader anticipating pleasantly the later fulfillment of his request.

Letters of Application

The purpose of a letter of application is to present the qualifications of the applicant for a position or appointment. Such a letter should indicate definitely the applicant's candidacy for the appointment.

Many personnel directors advise including with the letter of application a personal data sheet giving detailed information about the applicant. Nevertheless it is the function of the letter of application to select and emphasize the qualifications which particularly fit the applicant for the position in question, and the letter of application should never be permitted to become merely a covering letter for the data sheet. Though the letter frequently closes with a request for an interview it should not make a direct request for the position, since such a request would be both presumptuous and premature.

Since the letter of application is of great consequence to the writer, he should examine thoughtfully his training and experience with the object of selecting evidence of his fitness for the position. The tone of the letter of application should be confident but not aggressive. Facts stated simply and directly are far more convincing than extravagant claims to merit.

In the letter of application on page 452 the first paragraph is used to establish contact with the position, the second to indicate the applicant's candidacy for it. Though a complete data sheet accompanies the letter, the letter itself is sufficiently inclusive to establish the qualifications of the applicant. The original letter was accompanied by a transcript of university courses and credits; otherwise such information would have been included in the data sheet under the heading *Education.*

Informative and Explanatory Letters

A large number of the letters which scientists and technologists have occasion to write convey information or offer explanations. The examples on pages 456, 457, and 458 belong to this group.

The first one, in the form of a memorandum, presents in the first paragraph information which forms the basis for the second paragraph which requests appropriate action and explains the procedure to be followed.

The second example, also a memorandum, gives instructions for the filing of an annual report on work covered by a research grant. The use

of indented and numbered lists to emphasize specific points should be noted.

The third example opens with an informative statement which leads into the ensuing paragraphs of explanation.

Public Relations

The activities of scientific and industrial organizations frequently call for letters to establish and maintain good public relations. Such letters include announcements, invitations, letters of appreciation, congratulatory letters, and letters of thanks.

The example on page 459 is an announcement.

The next letter (see p. 460) extends an invitation to become a member of a professional society and defines the nature and aims of the organization.

The concluding example (see p. 461) is a letter of thanks.

While business letters are of immediate concern to the individual correspondent, they are perhaps of still greater importance in linking the work of the scientist in his laboratory with organized science and with a highly industrialized society. Many scientific enterprises have become big business in terms of the investment involved; the consequences of scientific work now in progress are potentially even greater. It is the obligation of society to provide an environment in which the scientist can work effectively; the scientist in turn can hardly escape the social implications of his work. In fulfilling the needs and resolving the difficulties of the groups associated in this social complex, the business letter and other types of business communications have a significant place.

UNIVERSITY OF LOUISVILLE
LOUISVILLE 8, KENTUCKY

SPEED SCIENTIFIC SCHOOL
JAMES BRECKENRIDGE SPEED FOUNDATION
DEPARTMENT OF ENGLISH

January 6, 19__

The Bureau of Educational
Research and Service
Extension Division
State University of Iowa
Iowa City, Iowa

Gentlemen:

Please give me information concerning the films and the booklets of selections which have been prepared by the State University of Iowa for use in developmental reading programs.

During a speeded-reading course at SUI last summer, one of the instructors told me that the films could be either purchased or rented, and he was quite sure that the booklets are priced at fifty cents per copy.

We are considering using the SUI material next fall, but we must make provision for it in the budget now.

Sincerely,

(signed)

Instructor

STATE UNIVERSITY OF IOWA
EXTENSION DIVISION

BUREAU OF AUDIO-VISUAL INSTRUCTION | IOWA CITY, IOWA | TEL. 8-0511 EXT. 2671

January 11, 19__

____
Instructor
Department of English
Speed Scientific School
University of Louisville
Louisville 8, Kentucky

Dear _______________:

In reply to your letter of January 6, under separate cover I am sending you a Manual of Instructions and Supplementary Reading material produced by Dr. Stroud of the University of Iowa.

The Supplementary Reading material is the manual that sells for 50¢ for one to five copies and 40¢ for all over five copies.

We do not reproduce the tests here at the University as most schools prefer to have their own tests duplicated from our sample set. Feel free to duplicate any that you would like.

The 14 reading films rent for $50.00 for a six-week period and the purchase price is $125.00.

If there is anything further that we can do for you, do not hesitate to call on us.

Sincerely,

(signed)

John R. Hedges
Associate Director
Bureau of Visual Instruction

JRH:jt

LIBBEY·OWENS·FORD GLASS COMPANY

SALES DEPARTMENT

TOLEDO 3, OHIO

E M EVERHARD
VICE PRES IN CHARGE OF SALES
E C WALBRIDGE
GENERAL MGR DISTRIBUTOR SALES DEPT
A P PLANT
GENERAL MGR INDUSTRIAL SALES DEPT

FACTORIES
TOLEDO OHIO
ROSSFORD OHIO
CHARLESTON W VA
SHREVEPORT LA
OTTAWA ILL
LIBERTY MIRROR DIVISION
BRACKENRIDGE PA

October 25, 1949

Mr. Robert D. Fowler
Department of Chemistry
The Johns Hopkins University
Baltimore, Maryland

Dear Mr. Fowler:

Thank you for your inquiry of October 21, concerning a sight glass for use in a pressure tank in which the maximum pressure on the glass will be 150 p.s.i. The exposed diameter of the glass window is 8"

Based on our calculations, a lamination of two pieces of 1/2" thick polished plate glass will provide a factor of safety of approximately 6 under the above conditions. This lamination should be satisfactory unless there would be hazard to personnel or valuable equipment in the event of glass failure. We assume that the lamination would not be subjected to temperatures in excess of 150° F.

Tuf-flex heat tempered plate glass in 1" thickness would provide a factor of safety of approximately 10.

Our authorized Baltimore distributors will be glad to give you delivery and price information. You will find their names listed in the classified section of your telephone directory:

We are herewith returning the sketch attached to your letter.

Very truly yours,

LIBBEY.OWENS.FORD GLASS COMPANY

(signed)

Manager Sales Technical Service

O.F.Wenzler:k

REYNOLDS METALS COMPANY

GENERAL OFFICES: RICHMOND, VIRGINIA

ADDRESS REPLY TO
GENERAL SALES OFFICE
2500 SOUTH THIRD STREET
LOUISVILLE 1, KENTUCKY

July 7, 19__

____
Pawtucket, Rhode Island

Dear Mr. ___________:

Replying to your letter received here June 18 and referring to statements in our booklet, THE ABC'S OF ALUMINUM, perhaps I can clarify your understanding a little bit, as it is evident you have a misconception of heat versus light reflectivity.

The reflectivity of any material varies with the color of the light striking it. Pure white light will give one reflectivity figure, blue light will give another, red light will give another.

As you know, all light waves are made up of energy vibrations at a certain frequency. If you increase the frequency and go outside the visible spectrum to the ultra-violet range, you will meet yet another figure.

Likewise, if you will decrease the frequency below the visible spectrum range, you will get into the infra-red region and get still another value.

Now when we are talking about heat reflectivity we are talking about reflectivity of energy in the infra-red region, which may or may not have any relation whatever to reflectivity in the visible spectrum. That is your first difficulty -- you are failing to realize that the difference in frequency of the energy you are talking about can give different reflectivity values.

The remainder of your difficulty comes from the fact that you are confusing the condition of the metal surface with reflectivity.

Mr. ____________ -- 2 July 7, 19__

You know from personal experience that the condition of the surface greatly affects the ability of the surface to reflect light in the visible spectrum. What you fail to understand is that the condition of the surface also influences the reflectivity in the infra-red (heat region), but the point is that this condition of the surface does not have as much influence on reflectivity of heat as it does on reflectivity of light.

So, you can see your difficulty stems from the fact you are assuming that the condition of the surface has nothing to do with heat reflection; when, actually, it does have a great deal to do with heat reflection. You see, surface conditions are important because heat is nothing more than a wave, just like light is -- the only difference being that it is a slightly different wave length.

I hope this explains to you what may have been bothering you.

Cordially yours,

(signed)

G. W. Birdsall, Director
Editorial Services

GWS:sp

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March 20, 19__

____
____
____
____

Dear Professor ________:

We wish to thank you for your recent request for the Mallinckrodt "Outline of the History of Chemistry."

The heavy demand for this chart has exhausted our original supply of 150,000 copies. While we look upon this as a compliment to our efforts, we regret that at this time we are unable to fill your request promptly.

We are now making a second printing and expect to be able to supply these charts again some time during the month of April. Your request will be kept on file until additional copies are received, at which time your chart will be forwarded.

We appreciate your interest in Mallinckrodt Fine Chemicals in general -- our more than 400 Analytical Reagents, and the "Outline of the History of Chemistry" in particular.

Yours very truly,

MALLINCKRODT CHEMICAL WORKS

(signed)

Divisional Sales Manager
Laboratory Chemicals

WFMichener
akg

314 North Second Street
___________, Minnesota
March 13, 19__

_____________, Head
Department of English
Speed Scientific School
University of Louisville
Louisville 8, Kentucky

Dear Dr. ___________:

The National Teacher Placement Service of Chattanooga, Tennessee, has informed me that you will have this fall an opening in the English Department of Speed Scientific School, the engineering college of the University of Louisville.

Because I feel that my training and experience fill rather well the requirements you set forth, I am sending for your consideration a detailed description of them.

Briefly, I have B. A. and M. A. degrees from The State University of Iowa and have almost ninety resident semester hours of credit in the graduate school there.

My teaching experience should be especially interesting to you. The first two years were as a graduate assistant in the College of Engineering of The State University of Iowa. The course, Technical Writing, was a combination of speaking and writing with emphasis on preparing technical articles for publication in the school's magazine (edited by students).

Subsequent experience is comprised of two years as full-time instructor in English at Brainerd Junior College, Brainerd, Minnesota. Here my teaching assignment has included two sections of traditional freshman English and one section of "Communications." The latter course has been a combination of reading, writing, and speaking.

Besides my regular teaching load, I have been faculty adviser to the student newspaper and annual, and I was in large part responsible for the publication of an illustrated publicity brochure for the junior college. I also taught a night school class in public speaking for local business men.

My high school and college debating provide a good background for coaching of a debate club, and, if you should feel that I otherwise have the qualifications you want, I could easily include in my summer school schedule at the State University of Iowa a course in Advanced Argumentation and Debate, which is offered "for teachers of speech and directors of debate in secondary schools and colleges with special study of the high school and college debate questions for the forthcoming year."

Thank you for your consideration.

Sincerely yours,

(signed)

____

Encs.

PERSONAL DATA

Personal

Name: ____________________

Age: 29

Height: 5'8½"

Weight: 165

Physical Condition: Good

Marital Status: Married

Wife: ____________________

Children: ____________________, ____ years

____________________, ____ years

Education

Parsons Junior College, Parsons, Kansas; Kansas State Teachers' College, Pittsburg, Kansas; The State University of Iowa, Iowa City, Iowa, B. A., 1947; M. A., 1949.

Armed Service Experience

Army Air Forces for 39 months. Administrative and clerical work as Medical Administrative Non-Commissioned Officer. Held grade of Technical Sergeant at time of honorable discharge.

Status today: Because of age, length of service, and dependents, I expect to be exempt from further military service. I am not now and have never been in any reserve classification.

Extra-curricular Experience

Editor of junior college newspaper. Editor of teachers' college paper. Baritone in church choirs, glee clubs, quartets, and a cappella choir. Leading parts in operettas in high school and junior college. Member of college English club and YMCA. Member of junior college debate team. Member of Married Students' Organization at State University of Iowa -- was village representative for two terms. Member of Methodist Church. Teach Sunday School class of young people.

Work Experience

General reporter for the Parsons Daily Sun, Parsons, Kansas for nine months. Left to return to college.

Clerk, Inventory Department of Business Office, State University of Iowa, for eight months. Left to take job as carpenter.

Apprentice carpenter in Ames, Iowa, and Iowa City, for five months. Left to become Graduate Assistant in English Department at State University of Iowa.

Clerk-typist and library assistant in Foreign Languages Library, State University of Iowa, for twelve months. Left to take teaching position in ________ Junior College, ______, Minnesota.

Delivery man for Meyer Laundry, ________, Minnesota, during summer of 1950.

Wrote advertising copy for KLIZ, radio station in _______, Minnesota.

Teaching Experience

Practice teaching, High School of University Experimental Schools, The State University of Iowa, one semester.

Graduate Assistant in English Department, State University of Iowa. Taught three semesters (five classes in all) of Technical Writing to junior and senior students in the College of Engineering.

Full-time Instructor in English at __________ Junior College, __________, Minnesota, for two years.
Two courses in traditional Freshman English.
One course in "Communication" -- writing and speaking, with emphasis on grammar and letter writing. Course is of the terminal education program.
Faculty sponsor of school newspaper and anuual.
Taught night-school class in speech for local business men.
Supervised ticket sales for athletic department.

NATIONAL RESEARCH COUNCIL

2101 CONSTITUTION AVENUE, WASHINGTON 25, D. C.

Established in 1918 by the National Academy of Sciences under its Congressional Charter and organized with the cooperation of the National Scientific and Technical Societies of the United States

DIVISION OF MEDICAL SCIENCES

COMMITTEE ON GROWTH
Acting for
THE AMERICAN CANCER SOCIETY

18 August 19__

MEMORANDUM TO: Grantees of the American Cancer Society

FROM: Hayden C. Nicholson, M.D.

The Engineers' Joint Council, a committee of the professional engineering societies representing chemical, civil, electrical, mechanical, mining and metallurgical engineers have indicated their interest in medical research and their desire to assist in its advancement. The Committee of Engineers Cooperating in Medical Research has been established in order to facilitate the application of the knowledge and techniques of engineering science to the solution of medical and biological problems. This group have shown a particular interest in contributing to the cancer research effort. The American Cancer Society of course welcomes the assistance of the Committee and wishes to do anything it can to help provide this engineering aid to cancer investigators.

It may be that in your own research project a problem has confronted you toward the solution of which engineering science can contribute effectively. If this is the case, will you please write to Mr. M. R. Runyon, Executive Vice President, American Cancer Society, 47 Beaver Street, New York, describing the problem in as much detail as you feel will be helpful to the engineering group. It may be that such problems have not arisen in your own investigations, but that there occur to you areas in cancer research or in medical research in general to which you feel engineering knowledge or techniques may be applied advantageously. Please follow the same procedure in this instance.

NATIONAL ACADEMY OF SCIENCES
NATIONAL RESEARCH COUNCIL

DIVISION OF MEDICAL SCIENCES

2101 CONSTITUTION AVENUE, WASHINGTON 25, D. C.

COMMITTEE ON GROWTH
Acting for
THE AMERICAN CANCER SOCIETY

5 June 19__

MEMORANDUM

To: Grantees of the American Cancer Society

From: O. M. Ray

Subject: Annual Report and Summary

As the end of the grant year approaches, I am writing to remind you of the requirement of a comprehensive Annual Report covering the work done under your Grant in Cancer Research during the past year. This report should not be more than 2,000 words in length. Although the report will be accepted up to 1 September, it would be greatly appreciated if it could be received as early as possible. Many investigators are away from their laboratories during much of August and a part of September and unless the report is prepared during July, it is often received too late to serve the needs of the Committee on Growth. In preparing this report, it would be helpful if you would follow the outline below.

1. Title of investigation
2. Name(s) of responsible investigator(s)
3. Name of institution
4. Text (not more than 2,000 words)
5. List of publications for the year 1 July 1949 - 30 June 1950 based on work done under this grant

With the comprehensive Annual Report, and in addition to it, will you please forward a brief summary (100 to 200 words) suitable for inclusion in the Annual Report of the Committee on Growth to the American Cancer Society. The Fourth Annual Report of the Committee, which was sent to you in March, contains summaries of all grants in effect during 1948-1949 and might be of some assistance to you in this regard. In preparing this summary, will you please adhere to the following form:

1. Title of investigation
2. Name(s) of responsible investigator(s), degrees, academic title, institution and location
3. Text (100 to 200 words)
4. List of publications for the year 1 July 1949-30 June 1950 based on work done under this grant

Department of HEALTH, EDUCATION, AND WELFARE • Public Health Service

National Institutes of Health • Bethesda 14, Md.

NATIONAL INSTITUTE OF ARTHRITIS AND METABOLIC DISEASES
NATIONAL CANCER INSTITUTE
NATIONAL INSTITUTE OF DENTAL RESEARCH
NATIONAL HEART INSTITUTE
NATIONAL INSTITUTE OF MENTAL HEALTH
NATIONAL MICROBIOLOGICAL INSTITUTE
NATIONAL INSTITUTE OF NEUROLOGICAL DISEASES AND BLINDNESS
THE CLINICAL CENTER
DIVISION OF RESEARCH GRANTS

AUG 6 1954

in reply refer
to our H-1503(C)

Doctor ____________
School of Medicine
University of Louisville
101 West Chestnut Street
Louisville 2, Kentucky

Dear ______________:

We are pleased to report that upon recommendation of the National Advisory Heart Council at its meeting on June 14-16, 1954, the Surgeon General has approved your application for a research grant.

The number, amount, period, budget categories, and recommendation in reference to additional years of support are specifically stated for this grant on the attached Statement of Research Grant Award. You may obligate these funds at any time after the beginning date shown on the Award Statement even though check in payment of the grant may be delayed several weeks.

A second attachment (INFORMATION REGARDING REQUESTS FOR CONTINUATION OF PHS RESEARCH GRANTS) pertains to requests for continuation of support of this project in succeeding years.

When you applied for this support you were asked to describe your research project in order that study section and council would have an adequate basis for review and recommendation of your request; but it is recognized that investigators must be free to follow promising leads. I wish to emphasize that, under Public Health Service Policy, you are permitted to deviate from your described plan and to pursue freely any leads which, in your opinion, are likely to be more productive than the plan described in your application.

Please let us know if you have any questions regarding these matters.

Sincerely yours,

(signed)

James Watt, M.D.
Director, National Heart Institute

Enclosures
cc: Dr. __________ Mr. ________

MIDWEST FOIL COMPANY
DIVISION OF COCHRAN FOIL COMPANY
500 E MAIN STREET
LOUISVILLE 2, KY.

December 17, 19__

Gentlemen:

We are happy to announce that Cochran Foil Company, of which Midwest Foil has been a division for nearly three years, has just acquired the Keller-Dorian Corporation of Fairlawn, New Jersey.

Keller-Dorian has long been manufacturing foil products similar to those produced by Midwest Foil. This means that the expanded facilities and strategically located plants of both Keller-Dorian and Midwest Foil are available to you. It is planned to combine the knowledge and experience of both companies into producing the best possible foil products. We feel confident that these pooled and diversified facilities will be of great advantage to you.

No changes in relations with any of our customers are contemplated. Just as in the past we shall always strive to make it easy to do business with Midwest.

Yours very truly,

MIDWEST FOIL COMPANY

(signed)

C. W. Huflage,
Vice President

THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION

PRESIDENT
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University of Texas
Austin 12, Texas

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Northwestern University
Evanston, Illinois

C. E. Watson, Asst. Secy.
Northwestern University
Evanston, Illinois

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Raleigh, N.C.

ECRC
E. A. Walker
Pennsylvania State College
State College, Pa.

March 16, 19__

Professor ______________
Speed Scientific School
Louisville, Kentucky

Dear Professor ___________:

A close associate of yours has highly recommended you for membership in The American Society for Engineering Education. I have the pleasure of extending to you this cordial invitation to join the Society.

The ASEE is an association of faculty members and administrators in engineering colleges throughout the country as well as industrial leaders who are interested in engineering education. Practically every accredited engineering college is an institutional member of this Society. Through its meetings and its publications, it provides a national forum for "the advancement of education in all its functions which pertain to engineering and allied branches of science and technology."

You will be interested in looking over the enclosed booklet describing the Society. The ASEE has 21 Divisions and numerous Committees which study every conceivable phase of engineering education, including the related fields of mathematics, physics, the social sciences and humanities. There is also a Division of Relations With Industry which maintains a close liaison between the engineering colleges and industry for the mutual benefit of both.

Membership in the Society includes a subscription to the Journal of Engineering Education. It entitles you to attend the Section Meetings of the Society as well as the Annual Meeting. Above all, it entitles you to enjoy the stimulating and challenging contacts with others of your profession throughout the country and to contribute your efforts to the growth and development of your profession.

Sincerely yours,

(signed)

President

WRW:ms

TELEPHONE JACKSON 0407

LOUISVILLE HEART ASSOCIATION, INC.

MISS EMMA KEATS CRUTCHER
EXECUTIVE SECRETARY

COLUMBIA BUILDING 401 W MAIN STREET
LOUISVILLE 2, KY

December 20, 19__

Dr. ______________
____
Medical School
101 W. Chestnut St.
Louisville, Kentucky

Dear Dr. __________:

On behalf of the Louisville Heart Association, I wish to thank you and those of your staff who cooperated so generously by holding "Open House" in your lab on Thursday, December 16 for the Boards of Directors of the Louisville and Kentucky Heart Associations.

The Research Tour was a most interesting and enlightening experience to the laymen. I heard a great many very enthusiastic comments.

Thank you again for being willing to interrupt your schedule for our behalf.

Sincerely,

(signed)

Emma Keats Crutcher
Executive Secretary

EKC/pw

An Affiliate of the American Heart Association and the Kentucky Heart Association

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